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THE

MALAYAN AGRICULTURAL JOURNAL

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MECHANISATION HALF-YEARLY REPORT, APRIL TO SEPTEMBER, 1956.

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Kuala Lumpur.

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THE MALAYAN AGRICULTURAL JOURNAL

The Journal is designed to present—as far as possible in non-technical terms—the results of the agricultural research, investigation and extension work in Malaya performed by the Department of Agriculture. Also, by means of selected articles, abstracts and reviews, this publication draws attention to the results of work of a similar nature in other countries, which have a bearing on agriculture in Malaya.

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THE

Malayan Agricultural Journal

Vol. 39, No. 4, 1956.

EDITORIAL

Rice Experiments and Investigations.

All three articles in this issue of the Journal deal with aspects of the Department's work on increasing and improving Malaya's rice crop.

The first two papers deal mainly with investigations into the cause or causes of the physiological disease of padi known in Malaya as *penyakit merah*. The disease does not usually affect padi seriously in this country but it may occur in most padi-growing areas and in some seasons and localities cause a serious loss of crop.

In one paper, Lockard and McWalter describe their investigations of the effects on rice of toxic levels of four elements. Iron and aluminium were the elements tested in connection with *penyakit merah* and, in addition, sodium and arsenic were investigated because some areas in which rice is grown in Malaya are liable to flooding by sea water and in others the land is irrigated with water that has been polluted with the water effluent from tin mines.

In the second paper, Lockard goes on to describe some of his work connected with deficiencies of major elements in rice. He used four varieties of rice and set out to show the deficiency symptoms of the various major elements.

As far as *penyakit merah* is concerned, it was thought at first that iron toxicity might be responsible for the disease. Alternatively, it was considered that the iron might be fixing the phosphate in the soil and so creating a deficiency of phosphate. The two investigations were made in an attempt to find the right answer and it is felt that, although the answer was not forthcoming, the theory is still correct and that *penyakit merah* is caused by a high concentration of iron in the soil, such a concentration resulting in a nutrient unbalance in the padi plant.

The third article, by D. S. Boyce, Agricultural Engineer, deals with the construction of and experiments with a prototype grain drier built, to American design data, in the Department's workshop at the Federal Experiment Station, Serdang.

EFFECTS OF TOXIC LEVELS OF SODIUM, ARSENIC, IRON AND ALUMINIUM ON THE RICE PLANT

BY

R. G. LOCKARD,

Plant Physiologist (Colombo Plan)

AND

A. R. MCWALTER,

Soils Chemist.

Introduction

In Malaya there is considerable practical interest in the toxicities of sodium, arsenic, iron and aluminium to rice and it was decided to test toxicity levels of these four elements using a sand culture medium. It was realised of course that toxic levels in the inert sand would probably be much lower than in soil, where these toxic elements are less soluble; nevertheless the experiments would reveal the concentration of water soluble toxic elements which the plant could tolerate.

The investigation on sodium was included since rice is grown in certain areas which are liable to sea water flooding. The soils in these areas often contain very large amounts of salt. In some places salt resistant varieties are grown quite successfully, but in new rice areas and in established rice areas that have had severe sea water flooding it is desirable to sample the soils and thus say whether rice would grow satisfactorily. To do this it is necessary to determine at what concentration sodium chloride causes injury and when it becomes lethal to rice plants.

Arsenic is known to be present in the water effluent from tin mines, and it has been suspected that when this water, or river water into which tin mine effluent is discharged, is used for irrigating rice, the crop may be adversely affected. Many samples of soil and water have been analysed for arsenic and though amounts have been generally low, a few samples have been found to contain quite considerable quantities. For example, a sample of water containing a heavy sediment was collected recently from a tin mine at the point of discharge into the river, and the water, when filtered, contained only 1 p.p.m. As_2O_3 but the amounts in the sediments varied from 1,200 to 2,000 p.p.m. As_2O_3. Such events inevitably bring rice and mining interests into conflict and make it desirable to know how much arsenic the rice plant can tolerate.

Iron and aluminium will be considered together since investigations on both were undertaken in connection with a physiological disease known in Malaya as *penyakit merah* (6). In the case of aluminium, it is

possible that this element can fix phosphorus in the plant roots (30) thereby resulting in a phosphorus deficient plant. Iron can either fix phosphorus in the soil (3), and thereby make it unavailable to the plant, or be present in such quantities as to cause iron toxicity, especially under reduced conditions. The symptoms of phosphorus deficiency were determined in another experiment and are reported elsewhere (16). In this experiment, only the effect of toxic concentrations of iron was tested. Rice plants were therefore grown in solutions containing excess aluminium or iron in order to compare the effects with the symptoms of *penyakit merah* which occur in the field.

Review of the Literature

The maximum level of NaCl at which plants will grow seems to vary considerably according to the type of plant used. Ahi and Powers (1) found that the critical levels for salt grass (*Distichlis spicata*) and alfalfa were 1,400 and 1,000 p.p.m. of the salt respectively. Hilgard (9) reported that the highest levels of NaCl at which plants, growing in soil, could continue growth were:—barley 0.25 per cent (2,500 p.p.m.), rye 0.09 per cent (900 p.p.m.), grasses 0.05 per cent (500 p.p.m.) and salt grass 3.53 per cent (35,300 p.p.m.). These figures are based on the NaCl, in lb. per acre, found in a 4 ft. depth of soil. Barcroft (2) found that in Iowa soils a concentration of NaCl at 3,600 p.p.m. would kill bean plants. Sand culture work done by Eaton (8) on several crop plants showed that in wheat 10 m.eq. of NaCl (585 p.p.m.) was slightly toxic and 50 m.eq. (2,925 p.p.m.) and 100 m.eq. (5,850 p.p.m.) were decidedly so. Plants in 200 m.eq. (11,700 p.p.m.) made little growth. Dennett (7) carried out experiments in pots to investigate the growth of rice in rice soils irrigated with salt water and used solutions containing 20 per cent, 2 per cent and 0.2 per cent NaCl. At 20 per cent the plants nearly all died, at 2 per cent many of the plants were sickly but at 0.2 per cent there were no visible ill effects. He concludes that rice is not likely to withstand over 2.0 per cent concentration of salt for a lengthy period.

Eaton (8), also, showed that, on the basis of growth-depression curves, there was no evidence of an abrupt point at which toxicity effects became pronounced.

The work of Magistad *et al* (17) showed that in sand culture the total concentration of salts (osmotic concentration expressed in atmospheres) was a greater factor in determining the amount of growth reduction than effects caused by specific ions.

Examples of the amount of sodium that is normally found in plants are given by Heinsen (12) who reported that, on a dry weight basis, clover straw had 0.132 per cent and soya bean plants 0.006 per cent.

There is very little information on the toxicity of arsenic in soils and none could be found regarding toxicity levels in sand culture. Reed

and Sturgis (24) reported that farmers in the rice area of south-west Louisiana experienced considerable difficulty in growing rice when it followed a crop of cotton which had been dusted with calcium arsenate. Experiments by Meyer (20) indicated that applications of 25 lb. per acre of calcium arsenate reduced the rice yield by 2 per cent, 200 lb. per acre reduced it by 60 per cent and 1,000 lb. per acre completely prevented growth. There is also evidence that rice is more susceptible to arsenic toxicity than are dryland crops. The reducing conditions under which the rice is grown appear to make the arsenic more available. Burnett (4) reported that rice growing in soil in pots showed visible retardation at 20 p.p.m. As_2O_3 and above. In addition, he records a stimulation of growth when the As_2O_3 was applied at rates between 1 p.p.m. and 5 p.p.m.

It has been suspected for some time that *penyakit merah* may be associated with a high content of mobile iron in the soil, and recently Ponnamperuma (22, 23) found that a high ferrous iron content in the soil was almost certainly associated with certain physiological disorders of rice similar to *penyakit merah.*

There is little evidence to show what constitutes a toxic amount of iron, but Ponnamperuma (22) found as much as 500 p.p.m. ferrous iron in his rice soils. Gines (11) tested numerous iron salts and found that a concentration of 28 p.p.m. was toxic to young rice plants.

There is no evidence as yet to connect aluminium and *penyakit merah,* but there is always a possibility that excess aluminium could upset the availability of phosphorus. This could result from precipitation of the phosphorus in the soil (5) or, more likely, from the fixation of phosphorus in the plant roots as found by Wright (27, 28, 29) and Wright and Donahue (30).

The toxic level of aluminium varies over a wide range for different plants. Some plants are injured by as low as 1 p.p.m. while others will withstand up to 80 p.p.m. of aluminium (10, 15, 18, 19, 25). However, Lal and Subba Rao (14) record that $AlCl_3$ at 0.00133 N. (12.0 p.p.m. Al) was toxic to rice seedlings. Narayanan (21) found that, on rice, toxic symptoms begin to develop at 1/7,500 N. $AlCl_3$ (1.2 p.p.m. Al). Villa (26) produced harmful effects on young rice plants by adding $Al_2(SO_4)_3$ or $Al(NO_3)_3$ at concentrations of 0.00025, 0.0005 or 0.00075 gram-molecule (6.7 p.p.m. to 40.5 p.p.m. of Al).

Description of the Investigation

The investigation on NaCl and As toxicity was carried out in one experiment, and that on iron and aluminium toxicity in another. Acid-washed river sand was used. Treatments were in duplicate with two plants in each 6 in. pot.

In the case of NaCl, the rice variety Siam 29, which is not resistant to salt, and two salt resistant varieties, Arong and Chubai 18, were used. Siam 29 was used for the As trial. In the Fe and Al test, three varieties were used: in one duplicate Pebifun and Radin Siak

34 were used and in the other Pebifun and Serendah Kuning. The seeds were germinated on moist filter paper and transferred to the pots after six days. The basic nutrient solution was the same for all treatments (Solution 1 given by Lockard (16)). A drip culture technique was used for the experiment on iron and aluminium but solutions were changed twice a week (topping up each morning) for the NaCl and As experiment. The plants were harvested at the flowering stage.

Treatments

SODIUM

The rates were as follows:—

(a)	400	p.p.m.	Na	(1,017.2	p.p.m.	NaCl)
(b)	800	,,	,,	(2,034.4	,,	,,)
(c)	1,600	,,	,,	(4,068.8	,,	,,)
(d)	3,200	,,	,,	(8,137.6	,,	,,)
(e)	6,400	,,	,,	(16,275.2	,,	,,)

Treatments were applied 14 days after planting.

ARSENIC

Arsenic was applied as sodium arsenate at the following rates:—

(a)	0.05	p.p.m.	As	(0.283	p.p.m.	Na_3AsO_4:12	H_2O)
(b)	0.2	,,	,,	(1.131	,,	,,	)
(c)	1.0	,,	,,	(5.653	,,	,,	)
(d)	5.0	,,	,,	(28.266	,,	,,	)
(e)	10.0	,,	,,	(56.532	,,	,,	)

IRON

It was not possible to maintain ferric citrate in solution under the conditions of the experiment and it was necessary to use chelated iron. The disodium salt of ethylene-diamine-tetra-acetic acid (Na_2EDTA) was used. The ratio of complexing agent to iron was 1.43, which is higher than Jacobson (13) recommends. The concentrations were:—

(a)	20	p.p.m.	Fe
(b)	50	,,	,,
(c)	100	,,	,,

In the control 6 p.p.m. Fe was used.

ALUMINIUM

Aluminium was supplied as aluminium sulphate ($Al_2(SO_4)_3$:18 H_2O). The rates were as follows:—

(a)	0.8	p.p.m.	Al	(9.874	p.p.m.	$Al_2(SO_4)_3$: 18	H_2O)
(b)	2.0	,,	,,	(24.68	,,	,, (	,,	)
(c)	4.0	,,	,,	(49.36	,,	,, (	,,	)

Results

SODIUM

Growth

Rice plants of the variety Siam 29 grew in concentrations of up to 1,600 p.p.m. of Na. Plate I shows some of the plants 10 days after the treatments were applied. The plants in the 6,400 p.p.m. Na treatment were already dead while all but one moribund plant in the 3,200 p.p.m. Na treatment had also died. At this time (10 days after application of the treatment) the plants in 400 and 800 p.p.m. Na were showing no adverse effects.

In Plate II, the plants are shown at time of harvest. The plants in one pot of the 1,600 p.p.m. Na treatment had died but the plants in the other pot, shown in the photograph, survived. It can be seen that the plants at all levels of Na were smaller than the controls.

The two salt resistant varieties were grown in 1,600 and 3,200 p.p.m. Na. The variety Arong was not nearly so resistant as Chubai 18. The Arong plants in 3,200 p.p.m. Na died after two months while those in the 1,600 p.p.m. Na grew fairly well. Chubai 18 proved much more resistant, and even in 3,200 p.p.m. Na the plants survived until harvest.

The oven dry weights of the plants at harvest are shown in Table I. It will be seen that the 1,600 p.p.m. Na treatment greatly decreased the growth of Siam 29 but had little effect on Chubai 18.

Table I

NaCl Experiment

Oven Dry Weights of Leaves at Harvest

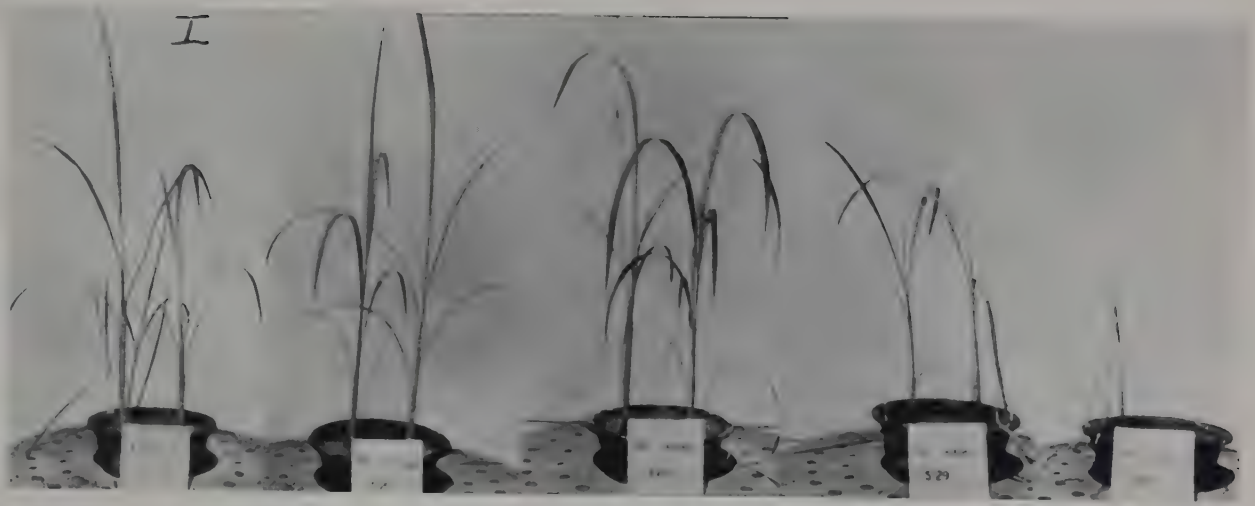
Rice Variety	Treatment	Weight (gm.)		
		Pot A	Pot B	Total (A + B)
Siam 29	Control	6.2	8.0	14.2
	400 p.p.m. Na	4.5	6.2	10.7
	800 „ „	6.8	9.2	16.0
	1,600 „ „	2.2	—	2.2
Arong	Control	9.7	11.6	21.3
	1,600 p.p.m. Na	6.4	4.0 *	10.4
Chubai 18	Control	4.9	5.2	10.1
	1,600 p.p.m. Na	6.4	3.5	9.9
	3,200 „ „	5.4	3.8	9.2

* Weight of one plant.

Toxic Symptoms

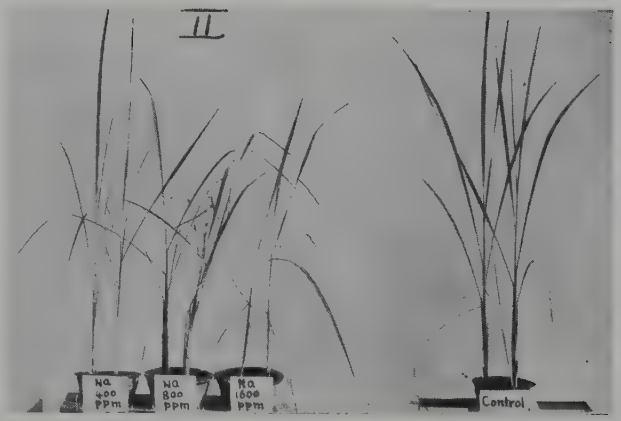
The leaves were very limp suggesting that the cells were flaccid.

PLATE I



Plants in excess sodium chloride 10 days after treatment was applied.
S 29 = Variety Siam 29.

PLATE II



Plants in excess sodium chloride 88 days after treatment was applied.

The damage was probably largely due to the high osmotic pressure of the solutions around the roots. A solution containing 1,068 p.p.m. NaCl (1,600 p.p.m. Na) would have an osmotic pressure of approximately 2.7 atmospheres due to this salt alone.

The dead leaves were affected by a fungus, a *Cladosporium* species. Dead leaves from plants in other experiments, e.g. arsenic, did not have this fungus and it is possible that the flaccid leaves allowed it easier entry.

Chemical Analyses

The leaves of the plant were ashed and analysed for P, K, Ca, Mg and Na. The results of analyses are given in Table II. From this table and Table I it will be seen that, in Siam 29, increasing amounts of NaCl decrease the uptake of the other nutrients. This decrease is particularly marked when the concentration of the Na rises from 800 to 1,600 p.p.m. This halves the percentage of phosphorus in the ash and greatly depresses the uptake of potassium. On the other hand, the amount of sodium in the ash goes up to a very high level.

Table II

Ash Analyses of the Leaves of Plants from the NaCl Treatments

Rice Variety	Treatment	Per cent Ash on D.M.	Percentage in Ash				
			P	K	Ca	Mg	Na
Siam 29	Control	8.55	4.47	23.68	2.52	3.88	1.13
	400 p.p.m. Na	8.40	4.88	21.17	1.34	2.82	5.34
	800 „ „	7.82	4.81	21.40	2.20	3.27	5.94
	1,600 „ „	12.84	2.31	13.87	1.62	2.23	16.06
Chubai 18	Control	9.46	2.94	21.26	2.52	3.86	1.19
	1,600 p.p.m. Na	9.66	3.34	17.32	2.72	3.65	3.17
	3,200 „ „	11.30	2.63	10.22	2.72	3.38	11.31

In the case of the salt resistant variety Chubai 18, the treatment with 1,600 p.p.m. of Na did not depress the phosphorous, calcium or magnesium uptakes and the potassium uptake is only slightly depressed. The most marked feature is that whereas the ash from the Siam 29 plants contained 16.06 per cent Na in the 1,600 p.p.m. Na treatment, the Chubai 18 plants contained only 3.17 per cent under the same treatment.

It would thus appear that the ability of the salt resistant variety to survive under conditions of high salt concentrations is due to its ability to absorb other nutrients in near normal amounts while only absorbing small amounts of sodium.

ARSENIC

Growth

Concentrations of arsenic up to 1 p.p.m. did not appear to have a detrimental effect on the growth of the plants, though a few of the older leaves of the plants in the 1 p.p.m. As treatment showed symptoms of arsenic toxicity. The treatments with 5 p.p.m. and 10 p.p.m. As had severe effects on the growth of the plants. This is shown by the harvest weights of the plants given in Table III and also in Plates III and IV.

Table III

Arsenic Experiment

Oven Dry Weight of Leaves at Harvest

Rice Variety	Treatment	Weight (gm.)		
		Pot A	Pot B	Total (A + B)
Siam 29	Control *	6.2	8.0	14.2
	0.05 p.p.m. As	7.0	6.0	13.0
	0.2 „ „	4.7	6.7	11.4
	1.0 „ „	5.0	6.7	11.7
	5.0 „ „	1.2	3.0	4.2
	10.0 „ „	Nil	Nil	Nil

* Same control as in Table I.

Toxic Symptoms

At first, the leaves had a tendency to curl and the dying tissues tended to be pink or light red in colour. In the later stages, the pink colour disappeared and the colour of the dead leaves was light yellow.

Table IV

Ash Analyses of the Leaves of Plants from the As Treatments

Rice Variety	Treatment	Per cent Ash on D.M.	Percentage in Ash				As p.p.m. on D.M.
			P	K	Ca	Mg	
Siam 29	Control	8.55	4.47	23.68	2.52	3.88	Nil
	0.05 p.p.m. As	9.15	4.20	22.31	2.81	3.69	1.5
	0.2 „ „	9.30	4.42	22.58	2.54	3.63	0.4
	1.0 „ „	8.55	5.06	23.98	2.51	4.16	3.0
	5.0 „ „	9.20	4.08	28.69	6.14	6.69	6.0

PLATE III

Plants in excess arsenic 10 days after treatment was applied.
S 29 = Variety Siam 29.

Control	As 0.05 ppm	As 0.2 ppm	As 1.0 ppm	As 5.0 ppm	As 10.0 ppm
S 29	S 29	S 29	S 29	S 29	S 29

PLATE IV

Plants in excess arsenic 88 days after treatment was applied.

Chemical Analyses

The plants were analysed for P, K, Ca, Mg and As. The results of analyses are given in Table IV. This shows that, as would be expected, increasing arsenic in the nutrient solution results in an increase in the amount taken up by the plant. The reason for the higher As in the 0.05 treatment than in the 0.2 treatment is unknown. It will also be seen from Table IV that the 5.0 p.p.m. As treatment greatly increased the uptake of calcium and magnesium and to some extent that of potassium but not phosphorus.

IRON

Growth

All plants in excess iron showed symptoms of toxicity approximately three weeks after transplanting. Plates V and VI show that growth was quite severely restricted by the chelated iron at 50 and 100 p.p.m. Fe. There was also some indication of a difference in varietal susceptibility because Radin Siak 34 appeared to be affected to a lesser extent than did Serendah Kuning whereas Pebifun suffered most severely of all. The weight of the plants at harvest is given in Table V.

Table V

Iron Experiment
Weight of Plants at Harvest

(weighed as harvested)
(gm.)

Treatment	Block A		Block B		Total of Four Varieties
	Pebifun	Serendah Kuning	Pebifun	Radin Siak 34	
Control	18.4	61.5	11.5	34.5	125.9
20 p.p.m. Fe	6.0	44.5	14.7	40.5	105.7
50 „ „	Nil	9.7	Nil	21.9	31.6
100 „ „	Nil	1.5	Nil	1.7	3.2

Toxic Symptoms

The symptoms of toxicity were not the same as those in *penyakit merah*. In cases of iron toxicity the leaf edges turn a very dark brown and roll in towards the mid-rib. In the orange-type *penyakit merah* (6) the leaves turn yellow but do not roll in, while in another type the leaves have many brown spots near the leaf tips but there is no rolling of the leaves.

ALUMINIUM

Growth

There was some reduction in weight of the Serendah Kuning and Radin Siak plants (Table VI), but since the reduction was greater at the lower concentrations, possibly little significance should be attached to it.

Table VI

Aluminium Experiment
Weight of Plants at Harvest

(weighed as harvested)

(gm.)

Treatment	Block A		Block B		Total of Four Varieties
	Pebifun	Serendah Kuning	Pebifun	Radin Siak 34	
Control	18.4	61.5	11.5	34.5	125.9
0.8 p.p.m. Al	18.7	44.0	12.2	16.4	91.3
2.0 „ „	10.5	47.7	6.7	19.0	83.9
4.0 „ „	5.0	57.5	13.2	23.0	98.7

Toxic Symptoms

There were no leaf symptoms which could definitely be attributed to Al toxicity. There was a tendency for the leaf lamina to break about 1 to 3 in. above the leaf base (Plate VIII). Some leaves turned white at the tips and a lighter green along the leaf edges. The leaf edges later turned a medium brown colour. However, the symptoms were not consistent and it is by no means certain that they were typical or indicative of Al toxicity.

Discussion.

In the introduction to this paper it was noted that this series of experiments was undertaken in order to throw some light on practical problems, and it remains to be considered how the information obtained from the experiments can be used. Dealing first with sodium, the great difference in varietal tolerance is emphasised and the analyses of the plants indicate why this may be so. It would appear from the experiment that non-resistant varieties such as Siam 29 suffer quite severely when the Na is much above 800 p.p.m. in the solution. If we take as the limit 1,000 p.p.m. Na, this is equivalent to 2,540 p.p.m. NaCl or 0.254 per cent.

It has been found that some of the rice soils in coastal areas, e.g. Bagan Tiang, a very high yielding area in North Perak, contain from

PLATE V

Plants in excess iron 46 days after germination.

P = Pebafun
RS = Radin Siak 34
SK = Serendah Kuning

PLATE VI

Plants in excess iron 108 days after germination.

PLATE VII

Plants in excess aluminium 46 days after germination.

Control		Al 0.8 ppm		Al 2.0 ppm		Al 4.0 ppm	
P	SK	P	SK	P	SK	P	SK

PLATE VIII

Plants in excess aluminium 108 days after germination.

0.13 to 0.2 per cent NaCl in the top 6 in. On the other hand, in an area nearby which had been flooded with sea water and where the rice failed completely, the percentage of NaCl in the soil was 0.39. Both these areas were sampled during the growing season when the soil was actually under water.

It is not possible of course to compare directly the value of 0.254 per cent, suggested as the upper limit for sand culture solution, with the amount of NaCl in soil. The amount in the soil would be higher, possibly twice as high, and the figure of 0.5 per cent is suggested as the upper limit in soils. If a soil contains more than 0.5 per cent NaCl it is suggested that salt tolerant varieties be planted.

The problem could also be examined by way of the rice plant itself. From the analyses carried out in this experiment it is obvious that if the plants of non-resistant varieties contain more than, say, 6 per cent Na in the ash they are likely to be suffering from Na toxicity.

As regards arsenic, it is even more difficult to say what concentration in the soil is toxic, but it is obvious from the results that a concentration of 5 p.p.m. As damages the plants. Arsenic is however fixed in the soil and though it may not dissolve when shaken with water it may gradually come into solution under the reducing conditions in which the rice is being grown. However, the experiment suggests that rice may suffer from arsenic toxicity when the As content of the plant is between 3 and 6 p.p.m. As. It would be possible therefore to use this figure as a guide when investigating cases of suspected As toxicity.

In considering the experiment on iron toxicity the first point to be noted is that the toxicity symptoms are not the same as those for *penyakit merah*, a finding which is somewhat at variance with the work of Ponnamperuma. The experiment shows that Pebifun is the most susceptible of the three varieties tested, but the other two varieties suffer quite considerable damage, even with 50 p.p.m. chelated iron. It would thus appear that even fairly low concentrations of mobile iron can exert quite serious effects on padi plants. It is appreciated, however, that chelated iron is taken up in greater quantities than free iron and the chelating agent may have a phytotoxic effect at such high concentrations.

The experiment with aluminium indicates that, with the concentrations used, rice suffered little from the effects of that element.

Summary

The results of two sand culture experiments on rice plants are described. In one, the toxic effects of sodium, as sodium chloride, and of arsenic, as sodium arsenate, were tested; in the other, iron, chelated with the disodium salt of ethylene-diamine-tetra-acetic acid, and aluminium, as aluminium sulphate, were tried out. The former was undertaken because of the existence of these substances in toxic amounts in the field, the latter because of the elements' possible connection with the rice disease *penyakit merah*.

Sodium and arsenic toxicities were tested on the variety Siam 29, and the iron and aluminium toxicities on the varieties Pebifun, Serendah Kuning and Radin Siak 34. The effect of sodium on sodium-resistant varieties was also examined.

Approximate toxic levels for sodium, arsenic and iron are suggested and the effect on plant growth, as measured by the plant weights, is presented.

The effect of excess sodium or arsenic on the content of major elements in the plant leaves is given, while the amount of sodium or arsenic in the leaves in their respective treatments is also given.

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THE FOLIAR SYMPTOMS OF DEFICIENCIES OF THE MAJOR ELEMENTS IN RICE

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Introduction

This work was undertaken in order to produce and record foliar symptoms of the major element deficiencies in rice. With practice it should be possible to identify the symptoms related to these deficiencies and thus have a convenient means for their recognition by the field worker.

Furthermore it was hoped that this work would also give some information on a physiological disease of rice known in Malaya as *penyakit merah* (1). In practice this name is applied to many physiological disorders of the rice plant and it would be desirable to separate the simple nutrient deficiencies from the more complex disorder *penyakit merah*. The symptoms of phosphorus deficiency are of special interest because of the element's possible connection with this disease.

The data presented here are the results of two experiments.

Review of the Literature

There is very little published data on the foliar symptoms of nutrient deficiencies in rice. The only reference noted was that on potassium deficiency (8) which, in Japan, produces brown spots on the leaves and grain. No further comment was made.

Tomoyoshi (7) found that, in water culture, if potassium was applied 35 to 45 days before heading it had a beneficial effect on the yield of grain. Sircar and Sen (5) reported that progressive phosphorus deficiency leads to progressive reduction in height and tiller number in rice plants.

Description of the Investigation

The experiments were carried out in sand culture. The containers used were 6 in. diameter clay pots coated on the inside with bitumen paint. River sand (particle size 0.5 to 2 mm.) was first washed thoroughly with water and then soaked in cold 5 per cent hydrochloric acid for several days; it was then rewashed with distilled water. In nearly every case Analytical Reagent chemicals were used and in Experiment I glass-distilled water was used; for Experiment II the water was purified in a permutit plant.

In Experiment I the rice variety Siam 29 was used and treatments were in duplicate with two plants to a pot. In Experiment II, three varieties were used; Pebifun and Serendah Kuning in one duplicate and Pebifun and Radin Siak 34 in the other.

In each case the seeds were germinated in petri dishes using distilled water. The seedlings in Experiment I were transplanted into the pots after seven days. In Experiment II, they were transplanted after 10 days.

The nutrient solutions are given in Table I. Rice grows better when both ammonium and nitrate nitrogen are present (2, 6), so a four salt solution was used. A different solution concentration was used in each experiment, Solution I being taken from a paper by Espiro and Estioko (3). The control plants in this solution were not dark green and growth and tillering were poor. For this reason Solution II was made up at a higher nutrient level; this solution is based on one recommended by Hewitt (4), though the major elements are not at the same concentration as he recommends. Better growth and tillering were obtained with this solution but some leaf-tip scorch appeared on the control plants.

In the preparation of solutions with one nutrient element deficient, the missing cation was replaced with sodium and the missing anion with chlorine.

Table I

Composition of Nutrient Solutions

Compound	Solution I	Solution II
	Milligram equivalents per litre in final solution	Milligram equivalents per litre in final solution
KH_2PO_4	0.75	1.60
$(NH_4)_2SO_4$	0.75	0.80
$Ca(NO_3)_2$	0.48	2.13
$MgSO_4:7H_2O$	2.00	2.40
Iron	0.058	0.197
$MnCl_2:4H_2O$	0.004	—
$MnSO_4:4H_2O$	—	0.02
$CuSO_4:5H_2O$	0.0004	0.002
$ZnSO_4:7H_2O$	0.0004	0.002
H_3BO_3	0.0099 (milli-mols)	0.033 (milli-mols)

In both experiments the nutrient solution was maintained in the pot at about 1 in. above the surface of the sand. In Experiment I, the solution was changed every five days during the first three weeks, topping up with distilled water to offset evaporation; thereafter the solution was changed every day. The nutrient solution was discarded after use. In

Experiment II, a drip culture was used and the depth of the solution in the pot was maintained with an overflow tube. The solution was run through at a rate of approximately five litres a day. The reservoir held 18 litres and this was re-used over a four-week period. Each time the solution was circulated, sufficient distilled water was added to compensate for evaporation and transpiration (which was 800 to 1,000 ml. a week).

In Experiment I, ferric ammonium citrate was used as a source of iron and, since the solutions were not open to the air until they were used, no difficulty was experienced in keeping the iron in solution. However, in Experiment II, where the solution was re-circulated, the ferric citrate was precipitated. To overcome this, a chelated compound, the disodium salt of ethylene-diamine-tetra-acetic acid (Na_2EDTA), was used, and iron was added at the rate of 5.5 p.p.m. In both experiments the pH was adjusted to 5.5.

The treatments in both experiments consisted of the reduction of nitrogen to one-half and one-tenth of the concentration in the control, while phosphorus, potassium, calcium and magnesium were reduced to one-third the concentration in the control or were completely absent.

Results

Observations were taken on the development of deficiency symptoms and these are described in detail for the variety Siam 29. On the other three varieties, observations were made where the symptoms varied from those on Siam 29, and these are discussed later. Illustrations of the deficiencies are shown in Plates I to VII.

Deficiency Symptoms on the Variety Siam 29

Nitrogen

The first symptom was the generally light green colour of the plant, with the older leaves lighter green than the younger ones. The tips of the older leaves then started to die back, turning reddish-brown at first and then becoming a light yellow. Necrosis first progressed down the leaf edges, but spread until all the leaf tissue was eventually involved. There was no sign of interveinal chlorosis in this process.

The main diagnostic symptoms at this stage were apparent in the necrotic portions of the leaves, which were light yellow, papery to the touch and, with few exceptions, unrolled. Plants suffering from severe nitrogen deficiency were also very stunted and had narrow leaves.

Phosphorus

The older leaves first turned light green at the tip and then yellow spots appeared in the interveinal tissue of the top one to two inches of the leaves. A small amount of reddening sometimes appeared in the tip area, but was usually confined to the very tip and leaf edges and preceded necrosis. Necrosis began at the tip and proceeded down the leaf edges, normally only two to three inches ahead of the general necrosis. Occa-
-sionally it proceeded rapidly down the leaf edges for three-quarters of

the length of the leaf. The dead tissue was always light brown in colour. Necrosis did not involve the mid-rib, with the exception of a small terminal portion, until the whole leaf died.

The necrotic areas were rolled inwards parallel with the mid-rib of the leaf. In more severe deficiency the green leaf took on a V-shape with the mid-rib at the bottom of the V, then as the leaf became necrotic it curled as in mild deficiency. Plants suffering from very severe phosphorus deficiency, in addition to exhibiting the symptoms just described, were stunted, though not to the same extent as those short of nitrogen, and had very narrow leaves.

Potassium

In practice it was often difficult to distinguish potassium deficiency from phosphorus deficiency because at certain stages the colour patterns were almost identical. In mild potassium deficiency the tips of the older leaves turned yellow and then the colour extended down the leaf edges for one to two inches. Necrosis then started at the tips and later progressed down the leaf edges. From the leaf margin to the mid-rib a sequence of colours could be observed. The peripheral light brown necrotic tissue bordered a thin line of reddish-orange and on the inside of this was an area of chlorotic tissue one-eighth of an inch or less in width. The marginal yellow band expanded into a wide zone near the dead tip, leaving only a green mid-rib. Often the mid-rib itself turned yellow in the transition zone between living and dead tissue. The yellow zone seldom showed yellow spots, as in phosphorus deficiency, and there was a sharper distinction between the yellow and light green zones than was observed on leaves deficient in phosphorus.

The yellow colour, and eventually the brown necrosis, extended rapidly down the leaf edges, often nearly to the base of the lamina, while most of the leaf was still green. The mid-rib, except near the leaf tip, was not affected until the leaf died (as in phosphorus deficiency). The dead tissue rolled in toward the mid-rib but did not make the leaf V-shaped as in phosphorus deficiency.

Plants suffering from severe deficiency, in addition to showing the symptoms just described, often displayed a symptom that was specific for potassium. This was a brown colour superimposed on the chlorophyll under the epidermis, resulting in an olive green colour in the leaf. The colour appeared first at the leaf tips and eventually covered the whole lamina except the mid-rib. The leaf gradually became darker in colour until it suddenly collapsed at the base of the lamina and died. The dead leaf was very dark brown but still retained an olive green hue. This colour could be detected at quite an early stage if the affected leaf was held up to strong, direct light. It was not possible to record this colour in the illustration.

Plants suffering from severe potassium deficiency were often dark green (before turning olive green) but were not stunted to the same extent as those lacking phosphorus or nitrogen.

Calcium

The mild symptoms were almost identical with those of potassium deficiency except that not so many leaves were affected. Plants were similar in size and only the oldest leaves were affected. Some interveinal clearing appeared on the older leaves of nearly mature plants and the newly formed leaves were light green in colour and translucent with prominent veins.

With severe calcium deficiency the leaves lodged early through collapsing at the lamina base, and this resulted in only two or three leaves being upright at any one time. The plants were spindly and weakly rooted. One leaf symptom of severe calcium deficiency was marked interveinal chlorosis. The interveinal stripes of yellow were prominent and extended to the base of the leaf. Later, the leaf tips became necrotic but did not roll. The dead tissue was a reddish-brown colour and included areas of mottled green where the chlorophyll had not completely disappeared before death occurred.

Necrosis commenced with the appearance of small brown spots at the tip, and the border zone between living and dead tissue was, therefore, mottled green and brown. As the brown spots increased in size and number they coalesced and the whole area became necrotic. The mid-rib died along with the lamina of the leaf, though the live portion of the mid-rib was usually dark green.

The appearance of a necrotic spot was first evidenced by a break-down in colour under the epidermis of the leaf; as necrosis progressed the spot became reddish-brown and the epidermal cells became affected.

Magnesium

The initial symptoms were very similar to calcium or potassium deficiency, i.e. yellowing leaf tips which later became necrotic. However, the plants soon displayed an interveinal chlorosis which was very pronounced and the older leaves lodged fairly readily. The mid-ribs of the leaves were usually not so prominent as in those showing calcium deficiency and the interveinal chlorosis tended to be more white or light green than yellow while the leaves themselves were light green. The lower half of the older leaves and all the young leaves had a clear translucent appearance.

The complete absence of Mg resulted in the most unhealthy plants in the experiment. Leaf collapse was very severe and usually only one leaf was upright and not more than three leaves were alive at one time. The plants never attained a height of more than 8 in. Each leaf, as it emerged, would start to roll parallel with the mid-rib, and shortly after it had completely emerged it was tightly rolled along its full length and usually lodged. The leaves were narrow and had interveinal chlorosis as already described. After lodging, the leaves shrivelled and died back from the tip, leaving a mat of dead leaves around the base of the plant. The dead tissue was medium to dark brown in colour and in the later stages the leaf sheaths on the main stem turned black.

Comparison Between Varieties

There was a certain amount of difference in the symptoms shown by the different varieties and, generally, the deficiency symptoms shown by Siam 29 in Experiment I were more severe than those shown by Serendah Kuning, Radin Siak and Pebifun in Experiment II. However, this was due mainly to different conditions existing in each experiment. Of the three varieties in Experiment II, Pebifun was the most severely affected.

In Experiment I an attempt was made to record the deficiency symptoms by means of colour photographs. Coloured drawings were also made of the plants suffering from potassium and magnesium deficiency. The colour photography was not successful in portraying the colour differences. In Experiment II only coloured drawings were used to record the symptoms. These were made to record the various stages in the development of the symptoms and not to show differences between varieties.

In Plate II the nitrogen deficiency symptoms in Radin Siak and Pebifun are shown. These symptoms were a little different from those in Siam 29 where the leaves had very pale yellow, in fact almost white necrotic tissue. In the other varieties the necrotic tissue tended to be more pink.

As previously stated, fairly marked symptoms of calcium deficiency, including interveinal chlorosis and early collapse of the lamina, were noted for Siam 29. However, no such well marked symptoms were shown by the three varieties in Experiment II.

Plates IV and VI show the potash deficiency symptoms in the different varieties. The olive green colour noted in the potash-deficient plants of Siam 29 is difficult to reproduce and Plate VI does not show it clearly. However, there were some varietal differences. For instance, the olive green leaves did not appear in the plants in Experiment II. The necrotic areas tended to be darker brown in the Siam 29 plants than in the other varieties.

As regards magnesium, there was considerable variation in the symptoms shown by the different varieties. Plate VII shows the narrow, rolled leaves of Siam 29. In Plate V the symptoms in Radin Siak and Pebifun are shown. The leaves of these plants did not roll up in the same manner and grew considerably larger. The leaves took on a speckled appearance and the necrotic tissue had a pinkish tinge.

Leaf Analyses

In Experiment I the plants were harvested when the grain (if formed) was mature, but in Experiment II it was decided to harvest the plant at the flowering stage and analyse the leaves for the major nutrients. Each plant was analysed separately but the results (Table II) for Pebifun are the average of the plants from two pots.

It is suspected that there was some nitrogen contamination of the

final nutrient solution applied before the plants were harvested, because they all assumed a greener colour and the nitrogen in the leaves was higher than would be warranted by the treatments.

The results of analyses are given in Table II and are discussed below:—

Table II

Analyses of Plants from Experiment II

(results expressed as percentage dry matter)

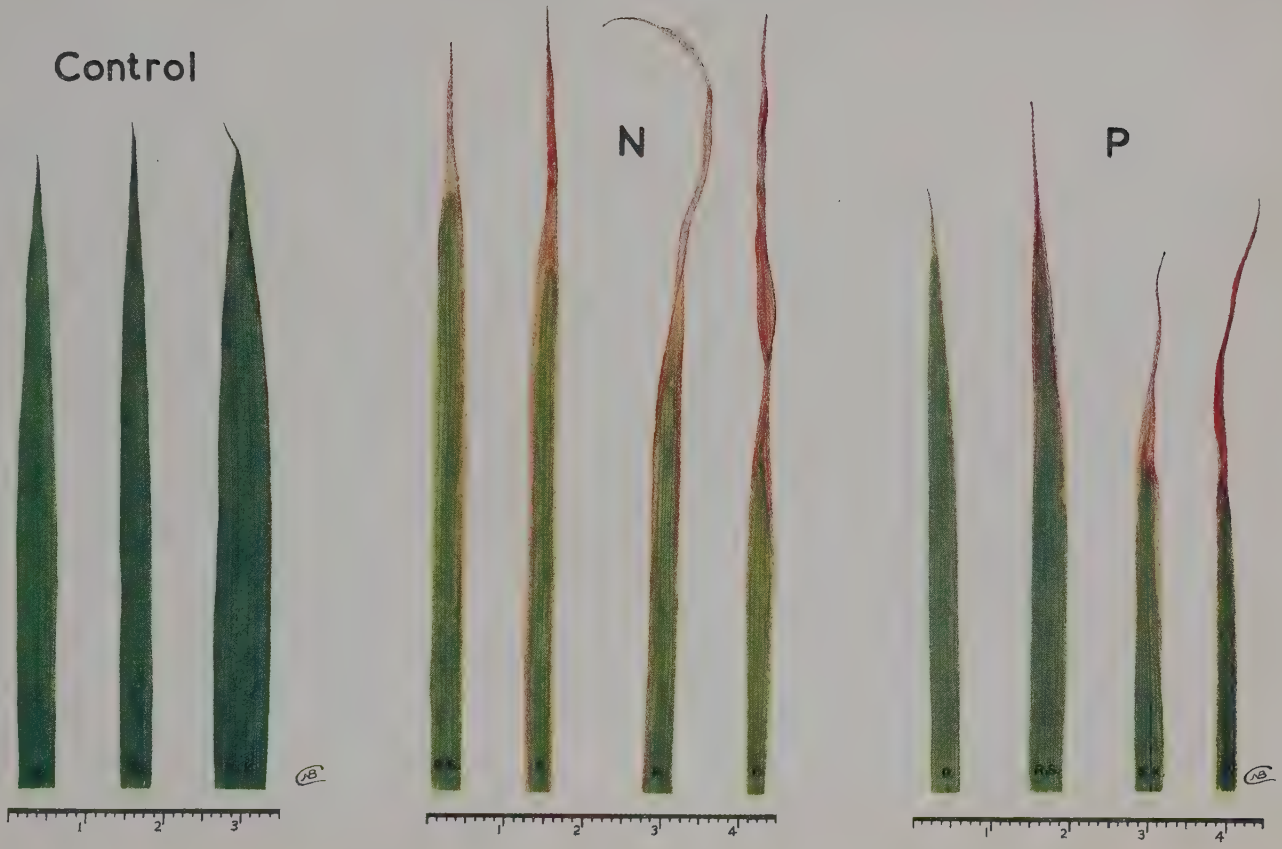
Variety	Constituant	Treatments										
		Control	1/2 N	1/10 N	1/3 P	0 P	1/3 K	0 K	1/3 Ca	0 Ca	1/3 Mg	0 Mg
Radin Siak 34	Ash	5.74	7.27	14.00	6.04	10.80	5.82	12.60	5.90	6.96	5.78	6.90
	N	1.20	1.11	1.20	1.47	2.57	1.40	3.08	1.71	2.26	1.56	2.06
	P	0.35	0.38	0.94	0.20	0.07	0.42	1.18	0.43	0.47	0.36	0.55
	K	1.33	2.14	3.50	1.81	2.90	0.78	0.99	1.59	1.73	1.49	1.64
	Ca	0.44	0.26	0.43	0.21	0.34	0.23	0.34	0.16	0.14	0.29	0.41
	Mg	0.46	0.30	0.42	0.29	0.28	0.41	0.85	0.37	0.52	0.18	0.16
Pebifun	Ash	9.13	10.36	10.20	9.57	10.00	8.60	9.63	11.73	11.65	10.96	11.03
	N	2.13	1.79	2.05	2.30	2.06	2.50	2.65	2.65	3.03	2.67	2.73
	P	0.62	0.66	0.47	0.38	0.07	0.58	0.74	0.97	0.72	0.85	1.02
	K	2.03	2.52	2.37	2.91	2.65	1.28	1.24	2.69	2.71	2.72	2.58
	Ca	0.32	0.34	0.44	0.29	0.32	0.31	0.30	0.34	0.26	0.46	0.48
	Mg	0.67	0.42	0.42	0.45	0.27	0.66	0.71	0.82	0.78	0.60	0.22
Serendah Kuning	Ash	6.80	10.50	16.29	7.72	9.08	8.70	13.50	8.30	9.93	8.62	11.70
	N	1.23	1.46	1.76	1.44	2.44	2.10	3.01	2.08	2.72	1.81	2.75
	P	0.45	0.98	1.03	0.28	0.06	0.75	1.20	0.64	0.98	0.69	1.01
	K	1.66	2.57	3.78	2.32	2.37	1.09	1.40	1.88	2.31	2.85	1.98
	Ca	0.24	0.38	0.45	0.21	0.43	0.37	0.43	0.28	0.21	0.39	0.48
	Mg	0.46	0.49	0.48	0.36	0.25	0.90	0.99	0.71	0.80	0.16	0.31

Nitrogen. Reduction of nitrogen had no effect on the N content of the leaf, and in fact increased it in Serendah Kuning. It increased the ash content to a large extent in two of the three varieties and markedly increased the uptake of P and K except in the Pebifun where the P content dropped with reduced nitrogen.

PLATE I

PLATE II

PLATE III

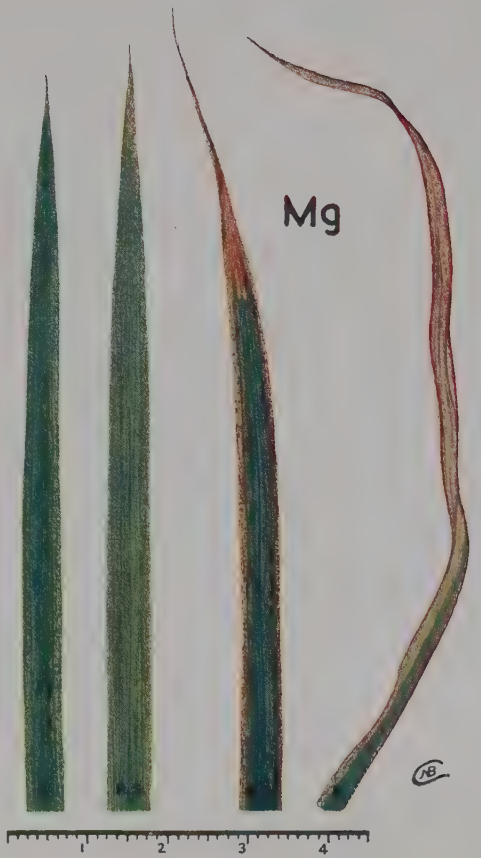


Foliar Symptoms of Nutrient Deficiencies in Rice.

NOTE: The affected areas in phosphorus-deficient leaves should appear more yellow in colour.

PLATE IV

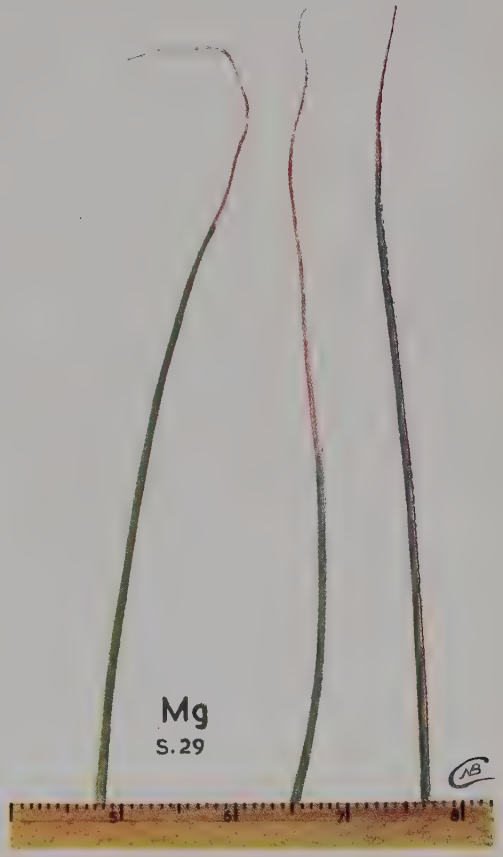
PLATE V



Foliar Symptoms of Nutrient Deficiencies in Rice.

PLATE VI

PLATE VII



Foliar Symptoms of Nutrient Deficiencies in Rice.

Phosphorus. Absence of P gave a very marked decrease in the P content of the plants. Potassium was taken up in greater amounts and calcium increased in Serendah Kuning at Po but there was a decrease in the uptake of Mg when P was lacking. Nitrogen increased in the Radin Siak and Serendah Kuning plants.

Potassium. Lack of K decreased the K uptake, although the plants with no potassium in the nutrient solution contained a considerable amount. The absence of K increased the uptake of P and Mg but had no consistent effect on the Ca content. Nitrogen was considerably higher in the Radin Siak and Serendah Kuning plants with a smaller increase in Pebifun.

Calcium. Plants lacking Ca were higher in N and also higher in K and Mg. There was some reduction in Ca, particularly in Radin Siak.

Magnesium. Lack of magnesium reduced the amount of Mg in the plants. There was a slight increase in K and an increase in P. Nitrogen increased considerably and Ca also increased in two of the varieties.

It should be noted that Pebifun contained considerably more N, P, and K in the controls than did Radin Siak 34 or Serendah Kuning.

Discussion

The investigation has shown that the varieties Pebifun, Radin Siak 34 and Serendah Kuning differ little in the deficiency symptoms they exhibit. The symptoms described for nitrogen, phosphorus, potassium and magnesium are probably fairly typical for these varieties as well as for Siam 29. Further work is needed to clarify the severe symptoms of magnesium and potassium. No consistent symptoms for calcium were obtained but it is considered that those obtained from Siam 29 are the type which could be expected. It would also appear from this study that deficiencies of phosphorus and magnesium show up more easily in the growth of the plant and the uptake of nutrients than deficiencies of potassium or calcium.

Summary

The results of two sand culture experiments are described. In the first, the variety Siam 29 was used, and in the second, the varieties Pebifun, Radin Siak 34 and Serendah Kuning.

Deficiency symptoms of nitrogen, phosphorus, potassium, calcium and magnesium are described for Siam 29. Plates showing the symptoms of nitrogen, phosphorus, potassium and magnesium deficiencies are presented. The results of the leaf analyses are discussed.

Acknowledgements

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Cheng for the original drawings and to Mr. P. Vamathevan, Agricultural Assistant, for assistance in carrying out the investigation.

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ASPECTS OF IN-BIN DRYING OF PADI IN MALAYA UTILIZING THE WASTE HEAT OF AN INTERNAL COMBUSTION ENGINE

BY

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Introduction

In humid regions it has been generally found impossible to harvest any grain crop at a time when it has naturally dried to a moisture content sufficient for prolonged safe storage and at the same time realize the maximum yield of dry matter. Davis in California (5) found that padi permitted to stand in the field after it had reached maturity deteriorated rapidly in milling quality due to sun-cracking. Padi harvested when its moisture content is below 20 per cent gives a low yield of padi heads. The common practice is to harvest padi when the moisture content is between 20 and 26 per cent.

In Malaya, under present conditions, padi is harvested by hand in small quantities and haphazardly cleaned and sun-dried. Should, however, large scale mechanical harvesting be introduced, more systematic and controlled cleaning and drying will be necessary if a quality product is to be produced. It will probably be preferable to introduce small cleaning and drying plants of an equal capacity to one or two harvesting units rather than to depend on large, centralised units relying on a vulnerable and complex transportation system. The advantages of artificially drying grain on the farm (7), compared with natural drying, are an earlier and more efficient harvest, a more favourable market price, and a product of assured quality at the end of the storage period. The best equipment for doing the job is that which will serve economically and effectively each year in handling a normal crop subjected to normal weather conditions.

Research data (6) indicate that certain moulds, bacteria and fungi are almost invariably present on normal padi grains and that their presence is harmless until the relative humidity (R.H.) reaches or exceeds 75 per cent at a minimum temperature of about 77° F. It is therefore necessary to reduce the moisture content of the padi mass to such a level that there is no possibility of this condition occurring. It has been shown (1) that the moisture content wet basis (M.C.W.B.) of padi at a temperature of 77° F and 75 per cent R.H. is 14 per cent, which is, therefore, the maximum moisture content allowable for safe storage. This value has in fact been accepted by Kramer (9) and Barr and Coonrod (4); however, as the average mean temperature of a grain mass in equilibrium

with ambient air in Malaya is liable to exceed a temperature of 77°F, and also as local millers appear to prefer a somewhat drier sample, it will probably be preferable to dry padi to a M.C.W.B. of 12 per cent initially.

There is little exact information concerning the safe maximum air temperature for drying to produce a product with superior milling qualities; however, there can be little doubt that an inferior sample will result at drying temperatures in excess of 130°F. Again, Kramer (9) and Barr and Coonrod (4) state that 110°F should not be exceeded if maximum milling qualities are to be maintained, and Barr and Coonrod state that incomplete tests have indicated that a temperature of 105°F may yield even better results.

An examination of the average maximum, minimum and 24 hr. daily average temperatures compiled over ten years by the Malayan Meteorological Service in several parts of Malaya indicates that if the drying air is heated in excess of +20°F, the safe limit of 110°F may be exceeded over considerable periods of the day. It must therefore be assumed, in the absence of a complicated and expensive system of automatic controls or the presence of a highly trained and responsible operator, that it is desirable to choose a drier heating unit which will not heat the drying air in excess of this safe value. Furthermore, it is desirable to choose a unit which is simple in design and operation, with minimum fire hazard and consuming a readily procurable fuel.

In addition to the fact that the maximum temperature of the heated air must be limited to insure a high quality product, it has also been pointed out by Downs and Compton (6) that there is a significant thermo-dynamic advantage in drying with moderate amounts of heat.

Malayan Conditions

Columns (1) and (2) of Table I show the average values, over a ten-year period (1931—1940), for mean maximum, mean minimum and 24 hr. mean temperatures and R.H. in the Alor Star area of Kedah in December, one of the important padi harvesting months. Though undoubtedly these values vary considerably from day to day and place to place, they are at least qualitatively applicable to large areas of Malaya.

Now, the force of evaporation (drying rate of air) is directly proportional to the difference between its absolute humidity and the absolute humidity of saturated air at the same temperature. In other words (6), the drying rate depends upon the difference between the weight of water actually in a given quantity of air and the weight of water that quantity of air can hold at any given dry bulb temperature. Table I quantitatively illustrates this law applied to the three air conditions recorded, when the temperature of the ambient air is increased by 20°F. It is found, generally, that the maximum ambient R.H. occurs at the minimum ambient temperature, and likewise the minimum R.H. occurs at the maximum ambient temperature.

Table I

The Change in the Theoretical Drying Rate of Ambient Air Heated by 20°F.

† Condition of Natural Air	Natural Air					Heated Air					Theoretical Increase in Drying Potential = Y/X
	Temperature (T °F) (1)	Relative Humidity (H %) (2)	Absolute Humidity (g.m./p.d.a. *) at T °F 100% R.H. (3)	Absolute Humidity (g.m./p.d.a. *) at T °F H % (4)	Theoretical Drying Potential = X (g.m./p.d.a.) (5)	Temperature ((T + 20) °F) (6)	Relative Humidity H^1 % (7)	Absolute Humidity (g.m./p.d.a.) at (T+20) °F 100% R.H. (8)	Absolute Humidity (g.m./p.d.a.) at (T+20) °F H^1 % (9)	Theoretical Drying Potential = Y (g m. p.d.a.) (10)	(11)
Minimum Temp. .... Maximum R.H.	71.3	97.1	117	114	3	91.3	52	225	121	104	34.67
Maximum Temp. .... Minimum R.H.	87.2	59.1	198	114	84	107.2	34	378	119	159	1.89
Mean Daily	77.9	83.2	144	124	20	97.9	47	282	126	156	7.8

* g.m./p.d.a. = grains of moisture per 1 lb. dry air.

† Average (1931-40) temperatures and R.H., December, Alor Star, Kedah. Compiled from returns supplied by the Malayan Meteorological Service.

The term 'theoretical drying rate' has been used advisedly, as in all calculations it has been assumed that the air leaving the drier would be saturated, which, of course, is not true in practice; nevertheless, the calculations do show that if the air is slightly heated its drying ability is greatly increased and it would be practicable, under the circumstances recorded, to run a drier 24 hr. per day.

Furthermore, it should be noted that the conditions most adverse to drying will occur at the given minimum and maximum temperatures when the ambient R.H. reaches 100 per cent, that is, therefore, during or after a fall of rain. In the case of air at the mean minimum temperature of 71.3°F and the mean maximum temperature of 87.2°F under conditions of 100 per cent R.H. being heated to 91.3°F, the R.H. of the air in each case will be reduced to 54 and 56 per cent. This is less than the equilibrium R.H. of padi at 12 per cent M.C.W.B. (1), and consequently it is not possible under these conditions for the drying unit to add rather than remove moisture from the grain mass and the needs for automatic controls or skilled operators are unnecessary.

Selection of a Drying Unit

To-date, in other parts of the world, most grain drying units have employed an electrically driven fan to force the drying air through the grain mass, the air being heated by either an oil or coke burner or an electric element. Both these methods of heating, and especially the latter, are advantageous in so much as the temperature of the drying air may be easily regulated, but in the former method there is an ever-present fire risk, and in the latter case a fairly large amount of electric power must be available. In addition, in both cases, a high investment must be made in permanent plant and skilled operators and maintenance personnel are required. In the last few years, considerable interest has been shown in drying units which depend upon an internal combustion engine to drive the fan forcing the air through the grain mass and, at the same time, waste heat is taken from the exhaust gases and the cooling air from the cylinder block to heat the drying air.

It appears from the popular literature that this method of drying grain is cheap and satisfactory in practice and has become popular in the United Kingdom (7 and 10). Furthermore, investigations with this type of drier at the National Institute of Agricultural Engineering, Silsoe, (11) under controlled conditions have proved the advantages and economy of the system. In view of these reports, and after considering the weather conditions in Malaya and the maximum allowable dry air temperature to which the padi may be subjected, it appeared that this type of unit would be quite feasible for Malaya.

Design and Construction of a Prototype Drier

There is of course little information upon which to base the design of a drier for Malayan conditions; consequently, in designing this drier, American data were resorted to. Initially, it was decided to force

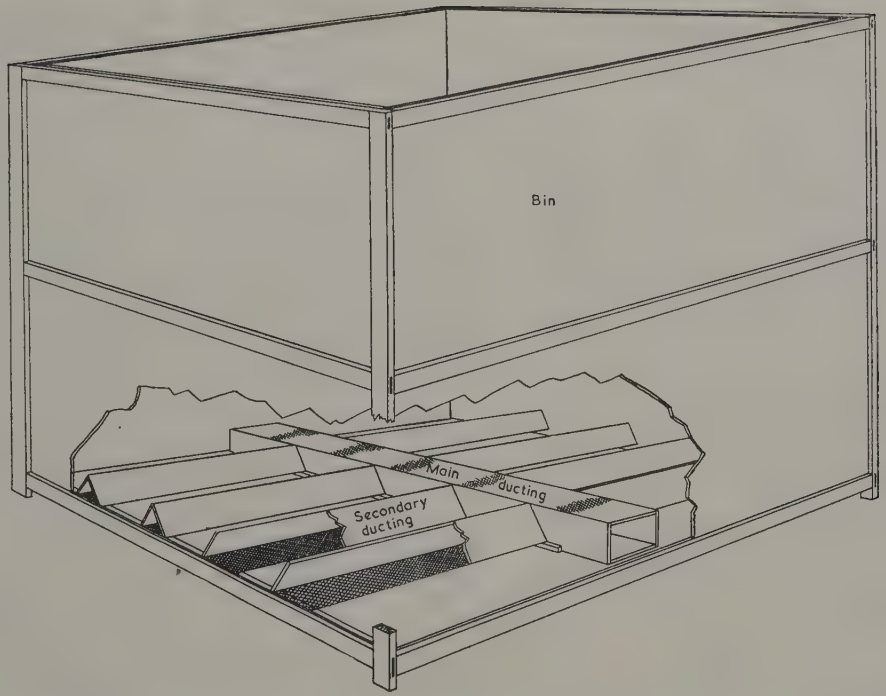
heated air through the grain mass at the rate of 3 cu. ft. per min. per cu. ft. of padi (7), as this had been recommended for in-bin drying of grain in America. Next, it was necessary to determine what static pressure would be developed in the drier ducting at this air rate. According to results obtained by Shedd (10), the expected static resistance of a 4½ ft. column of rough rice subject to this air flow would be 1.17 in. of water gauge; however, in practice, the average value of this factor was found to be about 1.125 in. of water gauge for the same height of padi. The slightly lower value may be accounted for by the fact that Shedd used grain columns of about twice this height.

There are in use a number of different ways of introducing the drying air into the grain mass. Perforated bin floors were initially very popular in the United Kingdom but they always pre-suppose a permanent structure, are initially expensive and in some cases offer considerable resistance to air flow. A much cheaper and less permanent method of introducing the drying air into the grain mass is by means of inverted vee-shaped, secondary ducts screened at the bottom and branching from a rectangular main duct. This type of ducting is shown schematically in Fig. I. It is important when designing such ducting to insure a minimum main duct cross-sectional area of 1 sq. ft. for each 1,000 cu. ft. min. air flow (7) if excess back pressure is not to be developed.

For the drier in question, a plywood bin was constructed with an estimated capacity of two tons and the appropriate ducting was installed on the bin floor. A J.A.P., 5 h.p., air-cooled engine was selected as the power unit, and this was belted to a single entry, 18 x 7½ in., back curve, six blade, centrifugal fan. A small, plate-type heat exchanger was fitted into a cowling at the fan intake. The engine exhaust gases were piped to the heat exchanger and then exhausted to the atmosphere through a long hose. The entire unit, fan and engine, was placed inside an asbestos casing to prevent the dissipation of heat from the engine and also to insure that the cooling air from the engine was directed into the fan inlet. Fig. II shows, schematically, the arrangement of the bin and drying unit.

In addition to the actual drying unit, provision was made for the installation, in the ducting between the fan and the drying bin, of a differential pitot static tube to measure air velocity and an outlet for measuring the static pressure within the system. A suitable holder was provided for a laboratory thermometer to record the temperature of the drying air in the duct. The pitot tube and static pressure outlets were connected to suitable U-tubes. A combination Casella dial psychrometer and thermometer was fixed near the drying bin to indicate ambient R.H. and temperature. The moisture content of the padi was determined with a Speedy Moisture Meter, and the actual dial reading was accepted as correct and all readings were duplicated at least three times. A platform scale was located near the drying bin in order that the weight of padi might be determined.

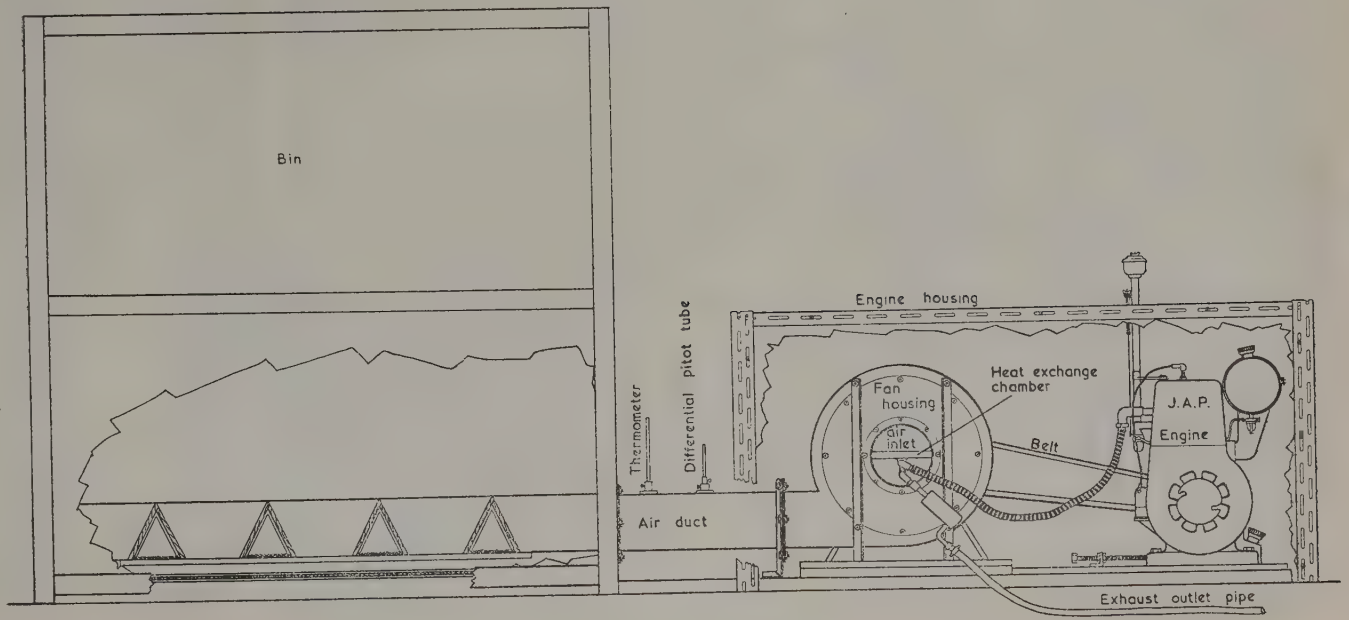
Fig. 1.



Schematic layout and detail of above floor ducting for in-bin drying.

Fig. II.

Schematic layout for in-bin drying using heated air from an internal combustion engine, showing engine, fan and heat exchanger.



Operation

Two batches of padi were dried during May and June, 1955, at the Workshop and Pool, Serdang, Selangor, and Table II shows numerical data concerning these batches. The padi was obtained from Tanjong Karang, Selangor, and consisted of a number of varieties mixed, although all of them were short grained. Very little trouble was experienced with the drier, though at first, due to the adoption of an unsuitable pulley ratio, the engine ran so slowly that it coked up rapidly: this fault was corrected by fitting more suitable pulleys. It would appear that with a high engine speed it will only be necessary to decoke the heat exchanger every 50 hr.

Table II

Rate of Moisture Removal

Batch No.	Initial M.C.W.B. of Batch (per cent)	Final M.C.W.B. of Batch (per cent)	Final Weight of Batch (lb.)	Average Rate of Moisture Removal (per cent per hr. per ton)
1	18.37	8.09	3,535.60	0.34
2	14.04	8.40	4,058.75	0.31

While drying the first batch, moisture determinations were made every hour at random points at a depth of 15 in. in the padi. Moisture content determinations were made less frequently during the second run as it was obvious that these readings were of no particular value because the grain mass was drying, layer by layer, from the bottom upwards. In addition to moisture determinations, hourly records were kept of ambient and duct temperatures, ambient R.H. and duct static pressure. Duct R.H. was estimated from a psychrometric chart. In addition, the volume of air delivered to the bin was checked hourly and, if necessary, adjusted. The ambient and duct hourly temperatures and relative humidities and, where applicable, padi moisture contents are plotted in Graphs I and II against time.

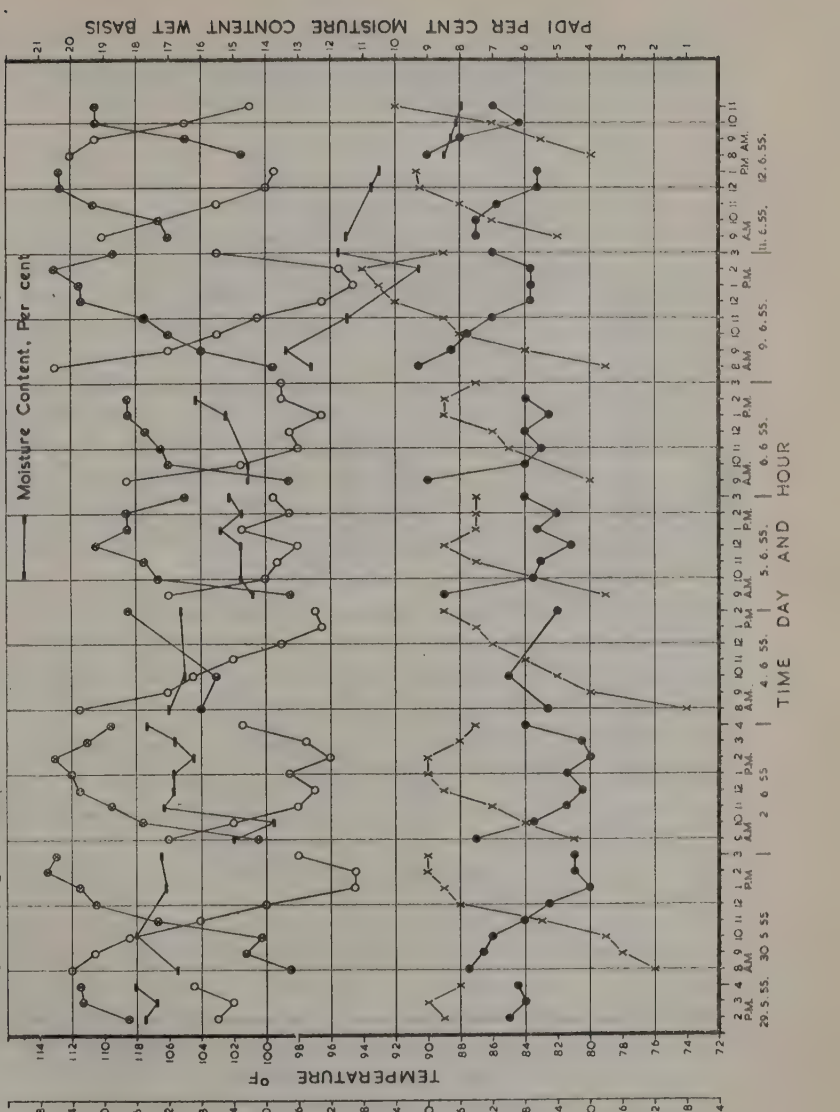
At the end of the drying period the padi was removed from the bin and weighed. Moisture content determinations were made at various levels in the bin as the dried padi was removed. The results, showing the variation in moisture content with depth, are shown in Graph III.

Discussion

It is immediately apparent from Graphs I and II that it would be impossible to achieve satisfactory drying by blowing unheated air through the grain mass under the conditions then prevailing. It is of

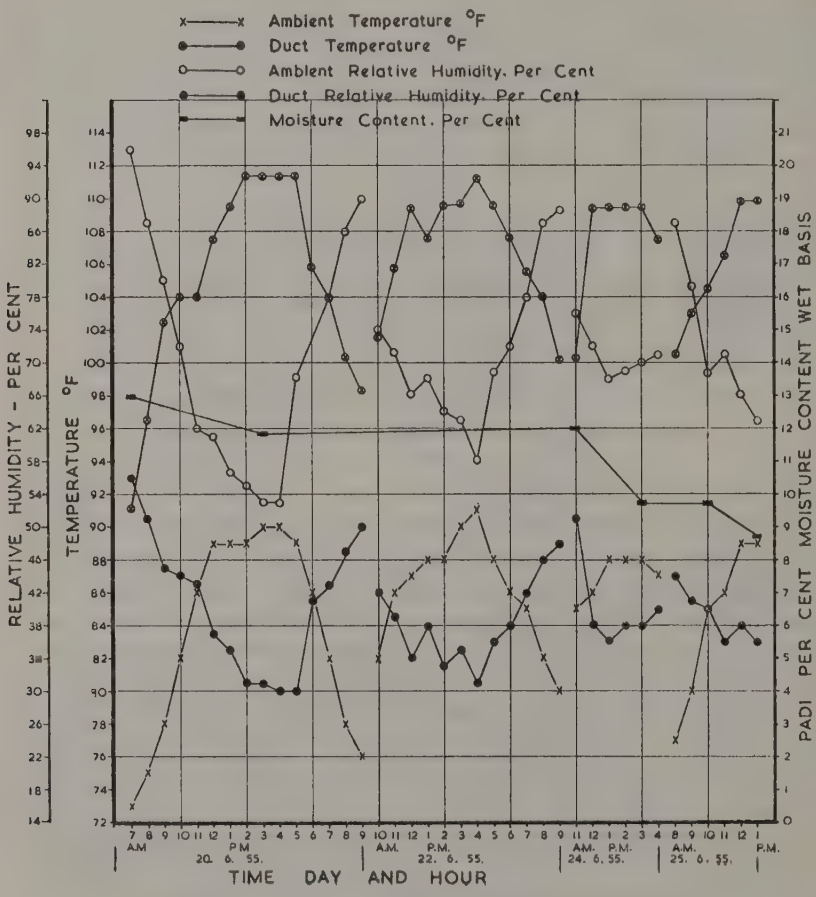
GRAPH I

Hourly Ambient and Duct Temperatures and Relative Humidities and Padi Moisture Content during In-Bin Drying. Batch No. I.



GRAPH II

Hourly Ambient and Duct Temperatures and Relative Humidities and Padi Moisture Content during In-Bin Drying, Batch No. II.



course very difficult to determine whether or not the weather conditions encountered during the drying period are representative of conditions liable to be encountered in the various padi areas of Malaya during harvest time. However, as it is characteristic that comparatively little rain falls during a harvest season and as a result of studying the meteorological statistics it is probable that conditions will seldom be less favourable and in most cases more favourable for drying. Furthermore, it has previously been demonstrated that even though rain is falling, the removal of moisture from the grain mass will continue, though at a low rate. It is also apparent that the average temperature increase due to the engine heating effect was somewhat in excess of 20°F. It will thus be necessary to provide some method of reducing the temperature of the drying air if ambient temperatures in excess of 88° to 90°F are encountered. This can be easily arranged by providing removable panels for the engine fan casing to allow, when necessary, ambient air to enter the fan after by-passing the engine.

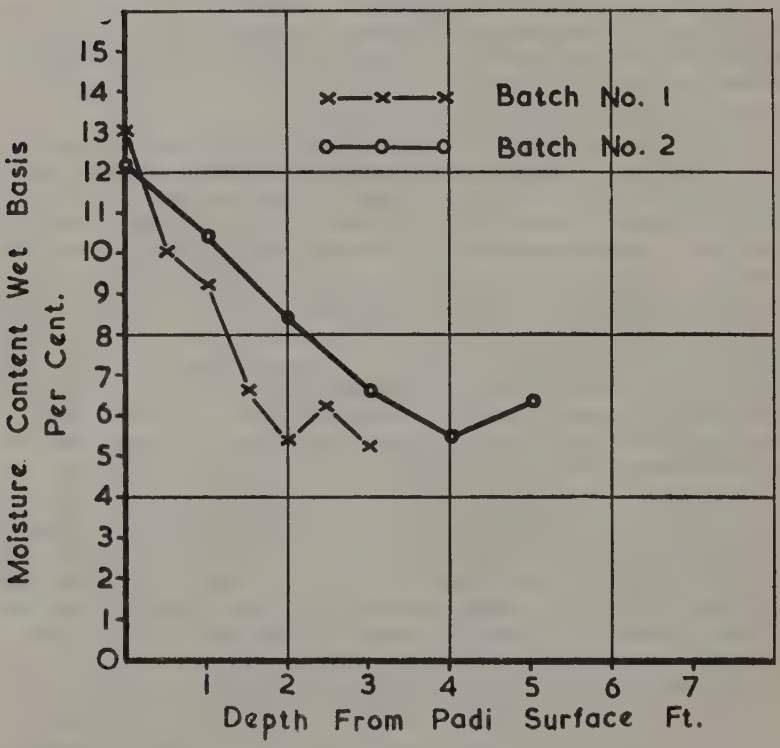
Graph III shows the variation in moisture content with depth of padi after drying. It is obviously impossible under these circumstances to dry the entire bin of padi to a uniform moisture content of 12 per cent wet basis. Over-drying, in addition to the added expense of operating the drier unnecessarily, reduces the weight of the product and, because padi is sold by weight, its value; furthermore, samples of a very low moisture content are probably unsuitable for milling. There are a number of ways in which a uniform dried sample of the correct moisture content may be produced. A uniform batch of grain of a given moisture content may be produced if the R.H. of the drying air is controlled at equilibrium R.H. of the grain at the desired moisture content; however, this would result in a low overall thermal efficiency as little energy would be required to heat the air, but the thermal efficiency of the internal combustion engine remains relatively constant regardless of the power required. The second method of insuring comparatively even drying would be to limit the depth of grain in the bin; this would of course require a drying bin with a very large floor area compared with its volume, resulting in a high initial cost per unit of drying capacity and would, of course, involve high handling costs.

The most obvious way to fully utilize the engine waste heat and at the same time insure that the drier is used to full capacity is to arrange to remove the padi from the bottom of the bin when it has dried to the correct level. This can be accomplished by fitting hand operated augers or paddle-type valves along the two lower edges of the drying bin. This method would also insure more or less continuous operations, as wet padi could be added at the top of the bin at the same time as the dried product is removed from the bottom.

Table II shows that the padi was dried considerably below the moisture content level required for safe storage. It should be noted that the rate of drying is less over a given range of low moisture contents than over a given higher range because the latent heat of vaporization

GRAPH III

Variation in Moisture Content with Depth of Padi after Drying.



of grain moisture increases as the moisture content decreases. Although the exact value of the latent heat required to vaporize moisture is not known, work carried out by Johnson and Dale (8) with wheat indicated that at low moisture contents, over 1,000 British Thermal Units (B.Th.U.) are required to evaporate 1 lb. of water from the grain. As the overall thermal efficiencies shown in Table III are calculated on this basis, they would, in fact, probably be greater than actually shown. In addition, no account has been taken of the friction horse power requirement of the engine, fan and transmission, so the actual value would be still higher; nevertheless, if the values given for thermal efficiency are accepted, they are still rather high for this type of process. Table III also shows the average rate of water removal in pound per hour per ton and pound per gallon petrol consumed.

Table III

Overall Thermal Efficiency

Batch No.	Lb. of Water Removed per Hr. per Ton Dried Padi	Lb. of Water Removed per Ton per Gal. of Petrol Consumed	Overall Thermal Efficiency * (per cent)
1	5.80	32.20	31.30
2	4.30	24.70	27.50

* Thermal Efficiency $= \frac{WL + \text{A.H.P.} \times (2{,}545) \times 100}{137{,}000}$;

where W = weight (lb.) of water removed per gal. of petrol used;

L = latent heat of vaporization of padi moisture;
= 1,000 B.Th.U. per lb. water removed; and

A.H.P. = air horse power
= volume cu. ft. per min. × pressure in. water gauge × 0.0001575.

It is probable that a unit of this type would be quite capable of dealing with the output of one or two large combines under normal harvesting conditions provided the padi was thoroughly cleaned before use. Kramer (9) mentions the case of a particularly dirty sample of padi which showed a moisture content of 37½ per cent, but the padi itself, when removed from the sample, showed only 22 per cent moisture content. The wet foreign material in combined padi not only reduces the capacity of the drier but also interferes with the uniform flow of padi in the drier bin and conveying system. On the other hand, combined grain which has not been dried is difficult to clean, as some weed seeds and empty grains may pass through the same size screen openings as the padi grains and when wet are too heavy to be removed by an air blast.

Furthermore, other foreign matter may be smaller than the padi kernel itself, and this matter usually becomes excessively dry and brittle in the drier and consequently breaks down to a fine dust in handling.

The second batch of padi dried was cleaned twice, once before and once after drying. During the first cleaning, mainly vegetation, straw, unthreshed padi heads and small, empty husks were removed. About 113 lb. of material was removed and the volume of the batch was reduced by about one-twelfth. At the second cleaning, a further 102.5 lb. of material was removed and the volume of the batch was reduced by about one-sixteenth. In this case, mainly empty husks and dust were removed. In both cases the cleaner was set to under-clean and no full grains were removed from the sample; nevertheless, the final sample appeared to be extremely clean. The cleaning operation was carried out with a Bentall Winnower, Mark W.A.1., Serial No. 385, driven by a small petrol engine.

When dealing with any food product it is as well to consider methods of protecting it from pests. In the case of padi, it is desirable to protect it from rats by suitable rat proofing and by making arrangements to dispose of any rats already in the area. When padi is exposed to the atmosphere, e.g. when it is in open bins, it is necessary to protect it from insects. After only a few days exposure in an open bin the batches under consideration were very heavily infested, to a depth of 18 in., by an insect identified as *Sitotroga cerealella*, the Angoumois grain moth. Such infestation could probably be prevented by installing a fine-mesh cover on the top of the bin.

It is of course impossible to give accurate costs for in-bin drying as described. Undoubtedly handling costs will be the most important in a process such as this, and with this type of drier the cost of plant and fuel will be small in comparison. In addition, it is unlikely, unless preferential prices are paid for well dried, well cleaned samples, that the individual grower will interest himself in drying and cleaning his crop. However, if handling costs are to be reduced to a minimum, a well arranged system of cleaning, drying, recleaning and final disposal of the product must be worked out for individual installations. It is obvious that each drying unit will have slightly different operational costs, but with a well organised unit working to capacity the less the padi is manually handled the less the unit will cost to operate.

Conclusions

1. Padi must be harvested at a high moisture content to obtain the maximum yield of dry matter.
2. If padi is to be kept safely for any length of time, the moisture content must be considerably reduced soon after harvest.
3. If the temperature of the ambient air is raised by about 20° F., it has been shown that
   (a) the maximum temperature which the drying air is likely to

achieve will not greatly exceed 110°F, the level above which milling quality is decreased;

(b) the absolute drying potential of the air is considerably increased;

(c) the percentage R.H. of the air at all times will be less than the percentage equilibrium R.H. of padi and air at a safe storage moisture content; and

(d) a comparatively rapid overall drying rate should be achieved.

4. Initial investigations indicated that a hot air drying system consisting of a petrol-engine-driven fan utilizing the engine waste heat would best fulfil the required conditions and at the same time be a simple, cheap unit.

5. A prototype drier was designed and built. The design was based on American data.

6. In operation this unit proved satisfactory.

7. Within the limits of the investigation the American design data proved to be applicable to Malayan conditions.

8. If full advantage of the drying unit is to be realized and a high quality sample is to be produced it will probably be desirable to subject the padi to pre- and after-drying cleaning.

9. It is important to insure that the drying padi is protected from pests at all times.

10. The overall costs of drying padi will depend on a well designed system for cleaning, drying, recleaning and final disposal or storage of the crop which minimizes manual handling.

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NOTES ON CURRENT INVESTIGATIONS AND EXTENSION WORK
JULY TO SEPTEMBER, 1956

Research

Padi

Varieties

Two trials of local varieties have been completed at Tangkak Padi Test Station in Johore and, in spite of lodging, Sm.29 has been consistently the highest yielder (2,687 lb. dry padi per acre). The short-medium term variety Acheh Puteh did nearly as well with 2,593 lb. per acre. Selentek was the best of the local Johore varieties but, over four years, averaged only 1,569 lb. per acre owing largely to severe pest damage in 1955-56.

At Dong Padi Test Station in Pahang, the short term Kedah varieties Radin Kling and Haji Haroun failed to do well, as was the case with these varieties elsewhere in Pahang and reported last quarter. Of eight short-medium term varieties tested, Leong Orn and Acheh Puteh gave excellent yields of over 3,680 lb. per acre over four years and should compare very favourably with the medium term varieties previously tested at this station.

In connection with co-operative trials organised by F.A.O. among Asian countries, 76 varieties from Pakistan, India, Indonesia, Philippines, Burma and Ceylon are being grown under observation at two experiment stations in Kedah and Malacca. The best of these will be included in yield trials next season and the results compared with those from the same varieties in the other countries mentioned.

Stem-Borer

Two years' work on padi stem-borer incidence and control in the Krian District of Perak has been completed and a report is in preparation for publication. The loss of crop from these pests in this district is probably at least 30 per cent and can reach 70 per cent or more in limited areas. The completed investigations show promise of largely controlling borers and minimising the damage they cause by spraying with suitable insecticides at the critical period, about three to four weeks before flowering. Further investigations are being undertaken to estimate the seriousness of the pest in other padi areas, to find the best insecticides to use for control with a minimum risk of damage to the fish population, and to search for borer-resistant padi varieties.

Cacao

A further consignment of cacao varieties for comparative trial has just been received *via* the Royal Botanic Gardens, Kew, England,

and includes pedigree Upper Amazon clones, high yielding Grenadan Trinitario types and the disease-resistant Lafi 7 from Samoa.

Diseases and Pests

A survey of the distribution and intensity of attack of the various natural enemies of cacao is being continued. Recent inspection of plantings in Trengganu, Perak and Pahang has confirmed that *Calonectria rigidiuscula*, causing die-back, occurs in all areas and is the most serious of the cacao diseases. A *Gloeosporium* leaf spot is equally widespread but rarely causes serious damage. Other parasitic diseases which may be sufficiently serious to require treatment include red rust (*Cephaleuros mycoidea*), white thread blight, brown root disease (*Fomes noxius*) and pink disease (*Corticium salmonicolor*).

Of the insect pests affecting cacao, *Helopeltis theobromae* is widespread and usually the most serious, causing considerable die-back to young shoots. Investigations are in progress to improve on the control given by fogging with DDT, which is not wholly successful. Little trouble from other pests such as *Apogonia* spp., stem-borers (*Zeuzera* sp.) and mealy bugs has been reported recently and control measures in use appear effective.

Processing

Comparative tests are being carried out on the effect of varying stages of ripeness of the bean, and varying time and temperature of fermentation on the quality of the resultant chocolate. Amelonado fermentations were carried out at 35° and 50°C in various time combinations totalling five to seven days. Results confirmed previous findings in that best results as regards chocolate quality were obtained by incubation for four days at 35°C followed by three days at 50°C. The same result has been obtained in one test using Trinitario beans; other types are to be tested.

Satisfactory chocolate has been obtained from Amelonado beans subsequent to storage at low temperatures. While chilling fresh beans at 1°C resulted in chocolate of poor flavour, a satisfactory flavour resulted after storage in a deep-freezer provided the beans had not been previously dried. It appears that in such circumstances death of the beans prior to fermentation does not necessarily prevent development of flavour precursors.

Chocolates prepared by the methods outlined above, from both Amelonado and Trinitario beans, compare favourably in quality with commercial samples and their flavours fall within the range allowable for West African cacaos. Comparison with samples made from beans obtained from Trinidad, the Gold Coast, Nigeria, Brazil and Grenada was favourable. It would appear that the microfermentation and chocolate testing methods in use are adequate for the detection of cacao strains with an inherently poor flavour. The detection of an outstandingly good flavour is likely to be more difficult.

SOILS

Nutrient Deficiency

Pot experiments with tomatoes grown in soils from the 'Deficiency Area' of Kelantan have been completed. A complete nutrient addition resulted in the best growth and farm yard manure induced good initial growth, though some deficiency (possibly minor element) symptoms appeared later. The response to addition of phosphorus, calcium and magnesium to these soils was very evident. Symptoms of minor element deficiency suggested the possibility of lack of molybdenum.

Agronomic and Livestock Investigations

PADI

Vigour in growth was outstanding where the straw had been burnt and guano had been applied. Overage seedlings, though manured in the nursery, made very slow recovery after transplanting. Although growth was satisfactory in the phosphate pellet experiment, no difference between the treated and untreated padis was yet noticeable.

Results from the 1955-56 season six plot and three plot phosphate trials on cultivators' land were analysed. These are not yet capable of yielding firm conclusions until data for two more seasons are obtained. There are suggestions however that phosphate in association with nitrogen can produce profitable responses and indications that double superphosphate is more profitable than Christmas Island rock phosphate in the east coast states.

CACAO

Height measurement in the Method of Establishment observation showed that, after one month, growth was significantly better when fertiliser was dispersed rather than pocketed. The difference disappeared for subsequent measurements. Higher figures were recorded for superphosphate.

COCONUT

The work of developing a new area at the Federal Experiment Station, Telok Bharu, Perak, was started, though somewhat late in the season. The two main operations were lalang eradication followed by the filling up of water holes and levelling with a disc harrow. Mechanical work had to be discontinued following the onset of wet conditions and lalang control was continued by spraying with lallicide.

Maintenance and observation were continued at Serdang. *Oryctes* continued to be a menace in spite of regular hand picking of the pests and the isolated location of the palms. First inflorescence in the manurial trial was produced.

PINEAPPLE

At Jalan Kebun, Selangor, three experiments were terminated and maintenance of the others was continued. Yield of Singapore Spanish

has been comparatively low and poorer yields were obtained from the Sarawak variety. A new trial (mulching) was laid down.

Application of potash from different sources did not show any difference in size and yield of Singapore Spanish and absence of potash depressed the yield. Magnesium continued to show beneficial effects. No difference in fruit size of Singapore Spanish was shown to be caused by minor elements, though copper somewhat reduced the yield as a result of its scorching effect.

Slow ratooning was observed in the Sarawak variety, markedly so where plants were widely spaced. Dry fertiliser application compared with spraying appeared to increase the yield and improve the size of fruits. There have been indications that fruiting is delayed somewhat by application of B.N.A. (beta-naphthoxy-acetic acid).

In Kelantan, experimental treatments, harvesting, recording and maintenance of experiments were continued. A complete NPK mixture produced the highest yield of fruits.

Progress was made in the mechanical eradication of lalang at Alor Bukit. A Ferguson tractor with a half-track attachment worked satisfactorily on peat where there were no underlying logs.

Tea

Experiments were maintained at Cameron Highlands. Considerable improvement in yield of green leaf continued to be obtained with the highest dressing of nitrogen.

Polythene was used on rooting beds at Serdang for observation as a possible substitute for resam (*Gleichenia*) cuttings.

Extension Work

Weather

Good early rains were experienced in Kedah and Penang but it was drier than usual in Perlis, Selangor, Negri Sembilan and Malacca. Elsewhere rainfall was normal with favourable distribution in Kelantan.

Padi

Some 600 acres of off-season *japonica* padi was planted in the Yen district of Kedah and it grew well. About 90 per cent had been harvested with a yield of 352 gantangs per acre. Quality and price paid were both low because of wet weather during harvest.

In Province Wellesley, 8,304 acres of off-season padi had been harvested by the end of September, the average yield being 450 gantangs per acre in the north and 319 in the south. The price paid for the padi ranged from $13.50 to $15.00 per pikul (133 1/3 lb.).

Some 27,146 gantangs (gallons) of pure-strain seed has been distributed to planters by the Department.

A considerable number of fertiliser demonstration plots has been put down this season. This includes 150 in Kedah to show the use of top dressings of nitrogen as granular urea. The high concentration of

this fertiliser makes it eminently suitable for the Kedah Plain with its poor communications. The total number of fertiliser demonstrations in the field is about 1,419.

Altogether, 330 demonstrations of nursery manuring with Ammophos 11:48 have been put down in Kelantan and Perak.

Seven seed farms have been planted in Malacca and two in Negri Sembilan. These serve the dual purpose of bulking up pure-strain, recommended seed and of demonstration.

An additional quantity of some 284 tons of fertiliser has been used for field manuring.

RUBBER

Steady progress with new and replanting has been reported and the following planting material has been distributed:—

Rubber Budwood			Clonal Seedlings	
New Planting (yd.)	Replanting (yd.)	Surplus Destroyed (yd.)	New Planting	Replanting
15,022	36,518	4,290	427,648	1,725,888

In spite of the keen demand for seedling stumps, a surplus is expected in Johore and Malacca. Budwood is also in plentiful supply and some surplus has to be destroyed in order to keep nurseries in steady production.

Damage by elephants, deer and wild pig to young holdings has been reported from Johore.

A poor seedfall of Tj.1 clonal seed is reported from Kedah and Pahang and a shortage next season is envisaged.

COCONUT

In West Johore satisfactory progress is being made with rehabilitation of smallholdings in the completed Senggarang Drainage Scheme. Cultivators have worked co-operatively on the clearing and widening of communal drains and catch crops of tapioca and bananas have been planted.

Oil mills in the Muar, Batu Pahat and Pontian Districts of Johore have been working at near full capacity and consumed some 86,395 pikuls of copra during the quarter.

In Province Wellesley, 710 selected seedlings were distributed to smallholders from Batu Kawan Estate at 20 cents each with free transport provided by the Department.

Prices paid for smallholders' copra ranged from $21 to $24 per pikul.

FRUIT

A total of 16,276 budded plants or marcots were sold by the Department during the quarter, to which must be added 314 seedlings.

Very poor yields characterised the rambutan and durian harvests in Kelantan and Trengganu.

TOBACCO

Satisfactory crops have been reported from the north of Kelantan but poor crops were harvested in Ulu Kelantan, where quality was reduced by wet weather.

COFFEE

In Malacca, 4,460 basketed seedlings of Liberian coffee were sold and orders accepted for nearly 10,000.

In Selangor, substantial planting is in progress in Kuala Selangor District. The price, however, remains low, ranging from $140 to $160 per pikul (Liberian).

Planting is also in progress in the Batu Pahat District of Johore.

VEGETABLES AND FOODCROPS

Colocasia and ginger are reported to be successful foodcrops for the bog soils of Johore; indeed the former, when manured with nitrogen, gives a better return than that obtained from tobacco.

There are now five demonstration plots of vegetable cultivation on degraded soils in the Cameron Highlands. These demonstrate correct use of compost, lime and balanced fertilisers and they have given impressive results.

CACAO

Work in the Trengganu pilot scheme has progressed according to plan with all participants working enthusiastically. The nurseries remained healthy and good progress was made with forest felling and thinning. Transplanting commenced in mid-September and it was found that the 12 men could carry from the nursery and plant 600 to 700 seedlings per day, so it will take 24 days to complete this year's planting.

PINEAPPLE

There is a good demand for fertilisers from the Johore smallgrowers and big co-operative orders have been placed by them in order to increase fruit size and yields.

Two new areas were being opened up, one at Parit Bharu, Muar District, where clearing of 400 acres had been started by the Co-operative Farming Society, which has 70 members. The other area consists of 600 acres at Parit Kasan Ahmad.

LIVESTOCK

Pigs

Some 71 weaner boars and 73 gilts were sold by the Department during the quarter. In addition, 375 services, mostly by Middle White pedigree boars, were performed at stud centres in new villages and elsewhere.

Poultry

Departmental sales during the quarter were:—

Cockerels	198
Pullets	161
Eggs for hatching	1,732
Eggs for consumption	24,878
Chickens	52
Ducks	4
Ducklings	742

Goats

Eighteen bucks and 25 does have been sold by the Department.

MECHANISATION

HALF-YEARLY REPORT, APRIL TO SEPTEMBER, 1956

Compiled by the Agricultural Engineer

Recent Importations

The following machines have been received:—

Hayter Motor Scythe
Rotary Hoe, Gem, Series IV
Hayter 6 ft. P.T.O.-Driven Grass Cutter

The following tractors and implements have been received by the Trans-Perak Pilot Mechanisation Farm:—

Ferguson T.E.F. 20 (diesel) Tractors
Ferguson Universal Seed Drill with Fertilizer Attachment
Swingfog Pest Control Unit SN.6.

Tests and Modifications

Dry Battery and Flame Hood for Swingfog Pest Control Unit SN.6

A new type of dry battery has been received for the Swingfog Pest Control Unit SN.6. The battery is housed in a metal box and is permanently connected to the starting coil. The existing wiring of the Swingfog Unit is not modified and external "dry" or "wet" accumulators may still be used if desired.

The battery box is installed in a convenient position under the starting pump and the press-button switch is readily accessible while pumping. The single wire to the coil can be pushed through the rubber grommets fitted to the high-tension cable, and the installation is neat and well protected from accidental damage. The new battery, with its box and wire, weighs about 1 lb., or less than half the weight of a "dry" accumulator with its wire and jack plug. The battery, which has a plastic case, provides adequate current for the coil and the unusually good starting characteristics of the Swingfog SN.6 are not changed.

The life of the new batteries under service conditions has not yet been determined. Replacement cells are somewhat expensive but it is thought that the new dry battery will be justified in areas where the re-charging and care of accumulators presents difficulties.

The Swingfog Pest Control Unit SN.6 may be used as a flame thrower by "fogging" petrol, kerosene or diesel fuel and burning the fog. However, a special flame hood must be used to mix additional combustion air with the fog. The flame hood, which is attached to the standard exhaust tube of the Unit, is of larger diameter than the exhaust nozzle and has a ring of holes through which combustion air is drawn. The operation of the Swingfog Unit flame thrower is straightforward, the kerosene or other fuel being placed in the formulation tank and the

fog/air mixture being ignited by means of a piece of burning rag or paper lying on the ground. The flame, which can be adjusted by means of the adjustable control valve, is intensely hot but the Unit does not become over-heated and can be used continuously as a flame thrower.

Investigations into the Cultivation of Wet Padi

Trials of Imported Animal-Drawn Ploughs

Further trials have been made in Malacca, Kedah and Kelantan with imported animal-drawn ploughs. Commercial models from Britain, Germany, Ceylon, India and Japan have been tested and compared with the indigenous implements.

The local Malacca type plough is of remarkably advanced design and no spectacular improvements can be expected from the introduction of imported ploughs into the Malacca area.

The Kedah type plough is less efficient than the Malacca plough and some of the imported models, especially those from Japan, were capable of much faster work under similar conditions. In one trial the best imported plough was 34 per cent faster than the Kedah plough and the average of all the trials showed an advantage of 21 per cent in favour of this particular model.

The Kelantan type plough has an efficient action but is not strongly made. Great interest was aroused by the mechanical construction of the imported ploughs but the quality of their work was criticised by the cultivators.

The results of this season's field trials have shown that there is considerable scope for improvements in the design and construction of the indigenous ploughs but that none of the imported ploughs are exactly suited to Malayan conditions. A general specification for an improved plough has been drawn up and it is hoped that a large batch of prototypes will be ready for extensive field trials during the 1957 cultivation season.

Investigations into the Cultivation of Dry Padi

Mechanical Threshing

Grain samples collected during the harvesting of the 1955-56 dry padi crop at Paya Besar, Pahang, have been examined for grain damage. The Rajah thresher used in these trials has a 17 in. diameter peg drum and a rather short, overshot concave. There are no transverse grain augers or elevators and it may be assumed that all damage occurred in the drum.

The average grain damage for all samples was 0.86 per cent. The maximum recorded was 2.66 per cent at a moisture content of 11.4 per cent and a high drum speed. The minimum was 0.29 per cent at a moisture content of 14.6 per cent and the recommended drum speed.

The results obtained followed the expected trends. Grain damage increased as the moisture content decreased, the increase being small between 19.4 and 13.4 per cent moisture (wet basis) but very large at

moisture contents below 13.4 per cent. Grain damage was at a minimum at the makers' recommended drum speed but increased rapidly at higher speeds and increased slightly at lower speeds. No differences in grain damage were found in the four varieties available.

Grain which had been stooked for a few days was more easily threshed than newly cut grain because the straw and weeds were drier, but grain losses through shattering during handling increased when the crop was stooked for more than two days.

The grain did not deteriorate when stooked in wet weather and, indeed, the grain damage after exposure to rain for four or five days was less than the average for freshly cut crops of the same moisture content. Very serious grain damage was recorded, however, in samples which had been stooked for five days in hot, dry weather. It has been shown that breakage during milling is increased if the grain is re-wetted after being dried to moisture contents below 14 to 15 per cent (wet basis), this increase in breakage being due to microscopic cracks formed in the grain on re-wetting. The equilibrium relative humidity for grain at 15 per cent moisture content (wet basis) is about 78 to 79 R.H., a value which is often exceeded in Malaya. It is thought probable that the grain in the stooks dries out below the critical moisture content during the heat of the day and is re-wetted by absorbtion of atmospheric moisture when the relative humidity rises. The microscopic cracks which appear form planes of weakness which lead to breakage in the thresher drum. During the combine trials in Kedah in 1953-54, it was noted that the moisture content of uncut padi grains followed a diurnal cycle and approached the critical value of 14 to 15 per cent at about 4 o'clock on a hot afternoon. It is therefore possible that the microscopic cracks may be present in the grain before it is cut. Such cracks would have been of little importance in the past, since hand threshing is a relatively gentle process, but they will have a marked effect on the management of mechanical harvesting equipment.

Trans-Perak Pilot Mechanisation Farm

The burning of windrows of felled timber was completed in June and the whole area was disc-harrowed twice. Small sticks and roots which were brought to the surface by the disc harrows were picked up by hand and removed in trailers. About 34 acres was dragged with a heavy "A" frame to level the soil and to spread the ashes from the burnt windrows.

There was a heavy growth of *Mimosa* on about 20 acres of the higher parts of area. The weed was successfully controlled by applying "Trioxone" with a low-volume, tractor-mounted sprayer.

The first padi was sown on the 15th August, rather less than a year after the site was occupied. It had not been possible to prepare the irrigation system for the higher land in time for planting and only about 25 acres of wet padi was sown, the remainder of the area being sown with dry padi.

All of the offices and staff quarters have been completed and selected coconuts have been planted on 2 acres of land at the building site. The farm has caused considerable interest in the district and there has been a large increase in the area cultivated by contractors' tractors: in August there were 15 privately owned tractors at work on the neighbouring padi land.

Departmental Notes

Promotions

Mr. R. Henderson, M.C., Agricultural Officer, was promoted to Senior Agricultural Officer with effect from the 11th July, 1956.

Enche Basir bin Ismail, Agricultural Assistant, to be a Pupil Agricultural Officer with effect from the 20th July, 1956.

Enche Khalid bin Abdul Rahman, Agricultural Assistant, to be a Pupil Agricultural Officer with effect from the 20th July, 1956.

Appointments

Mr. Lim Seang Yew, General Clerical Service, acted as Financial Assistant from the 1st October to the 31st December, 1956.

Mr. S. J. Navaratnam was appointed Pupil Plant Pathologist with effect from the 3rd November, 1956.

Mr. H. J. Simpson, P.J.K., Assistant Director of Agriculture (Field), was appointed to act as Deputy Director of Agriculture with effect from the 7th November, 1956.

Mr. A. L. Barcroft, Agricultural Officer, was appointed to act as State Agricultural Officer, Kedah & Perlis, with effect from the 8th November, 1956.

Mr. J. R. Milburn, Agricultural Officer, was appointed Settlement Agricultural Officer, Penang, with effect from the 10th November, 1956.

Mr. E. F. Allen, Senior Agronomist, was appointed to act as Assistant Director of Agriculture (Field) with effect from the 14th November, 1956.

Mr. J. Chattaway, Agricultural Officer, was appointed Senior Lecturer, College of Agriculture, with effect from the 22nd November, 1956.

Mr. Oh Cheng Tew, General Clerical Service, was appointed to act as Office Assistant with effect from the 26th November, 1956.

Mr. H. D. Matheson, Agricultural Officer, was appointed to act as State Agricultural Officer, Selangor, with effect from the 30th November, 1956.

Transfers

Enche Mohamad bin Jamil, Agricultural Officer, from the post of Agricultural Officer, Perak South, to that of Agronomist (Headquarters) with effect from the 1st December, 1956.

Mr. R. J. R. Barrett, Agricultural Officer, from the post of Agronomist (Negri Sembilan) to that of Agricultural Officer, Perak South, with effect from the 1st December, 1956.

Mr. Low Kim Ann, Office Assistant, to the Selangor Secretariat with effect from the 1st December, 1956.

Mr. B. C. Balbernie, Agricultural Officer, transferred to the Department of Agriculture, Sarawak, with effect from the 21st December, 1956.

Leave

The following officers have returned from leave:—

Mr. A. L. Barcroft, Agricultural Officer, on the 4th November, 1956.

Mr. E. F Allen, Senior Agronomist, on the 14th November, 1956.

Mr. O. M. Lee, Principal, College of Agriculture, on the 21st November, 1956.

Mr. H. D. Matheson, Agricultural Officer, on the 21st November, 1956.

Mr. A. R. McWalter, Chemist (Soils), on the 19th December, 1956.

The following officers have proceeded on leave:—

Mr. D. L. Stacey, Agricultural Officer, on leave prior to retirement under the Pensions (Entitled Officers) Ordinance, 1956, on the 18th October, 1956.

Dr. C. C. Webster, Deputy Director of Agriculture, on leave prior to retirement under the Pensions (Entitled Officers) Ordinance, 1956, on the 8th November, 1956.

Mr. P. A. Gething, Senior Agricultural Officer, on the 29th November, 1956.

Mr. C. Whitehead, Agricultural Officer, on the 21st December, 1956.

MARKET PRICES

July to September, 1956

Rubber.—The noon price for R.S.S. No. 1 (f.o.b. in bales, buyer) in Singapore on Monday, the 2nd July, was 85.125 cents per lb.—nearly four cents lower than it was on the last day of June. However, the lower price was not long lived, and by the 12th of the month R.S.S. No. 1 was being bought at 96.375 cents per lb. The price was lower during the next 12 days but reached 98.75 cents on the 30th July. The average price for the month was 92.365 cents.

August arrived with the price at 101.25 cents—the first time it had been above $1 per lb. since March, 1956. On the 11th August the price was 104 cents but dropped off after that and was never above $1 per lb. in the second half of the month. The price was at its lowest on the 31st August, when it was 96 cents. The average price for August was 99.95 cents.

The decline in price continued in September, until it was 88.5 cents per lb. on the 25th. The price rose in the last four days but only to bring the average price for the month to 92.16 cents. The highest price in September was 95.75 cents, on the 1st.

The prices given above are those reported by the Singapore Chamber of Commerce and they have been taken from the Monthly Statistical Bulletin of the Federation of Malaya.

The average prices paid for smallholders' rubber at three towns in the Federation of Malaya are given in Table I.

Table I.

Average Monthly Prices Paid by Local Dealers for Smallholders' Rubber, July to September, 1956

(Dollars per pikul of 133 1/3 lbs.)

Grades.	Taiping, Perak.			Seremban, Negri Sembilan.			Batu Pahat, Johore.		
	July	Aug.	Sept.	July	Aug.	Sept.	July	Aug.	Sept.
Smoked Sheet No. 1	101.76	108.02	102.73	101.23	109.36	103.05	—	—	—
Unsmoked Sheet	83.30	87.16	85.53	79.72	86.35	84.36	84.28	91.04	86.80
Scrap	41.16	43.68	41.92	52.22	53.49	50.99	30.80	28.32	26.72

This table has been compiled from statistics supplied by the Chief Statistician. Federation of Malaya.

Palm Oil.—The average prices paid in London during the three months for oil shipped by the Malayan Oil Palm Pool were, per ton: July £83.75; August £86.75; and September £90.5.

Tea.—In his monthly bulletin, the Chief Statistician, Federation of Malaya, reports that 1,239,000 lb. of black and green teas were produced during the quarter.

The average prices paid for Ceylon teas at the sale held in Colombo on the 25th September, 1956, and as reported in the Weekly Tea Market Report of the Colombo Brokers' Association, were, in rupees per lb.:— High Grown Teas (4,000 ft. and above) 3.02; Medium Grown Teas (2,000 to 3,999 ft.) 2.15; and Low Grown Teas (below 2,000 ft.) 1.83.

Derris.—The average Singapore prices for derris were, per pikul: July $130; August $130; and September $126.25.

Table II.

Singapore Prices of Various Agricultural Products.

(Dollars per pikul)

Date	Copra, Sundried	Coconut oil *	Pepper. F.A.Q. Muntok white	Pepper. Gen. Muntok white	Gambier, Cube	Sago Flour, Lingga	Tapioca Flour No. 1	Oilcake, Round
1956								
2nd July -	29.50	42.50	100.00	110.00	42.00	12.75	17.50	16.00
9th July -	26.125	43.00	109.00	119.00	48.00	12.75	17.50	15.25
16th July -	25.75	42.50	121.00	131.00	48.00	12.75	17.50	15.50
23rd July -	25.75	43.00	109.00	110.00	48.00	12.75	17.50	15.75
30th July -	26.00	43.00	118.00	128.00	48.00	12.75	17.50	15.50
7th Aug. -	25.875	43.00	134.00	144.00	48.00	12.625	17.50	15.50
13th Aug. -	26.50	44.00	126.00	136.00	50.00	12.75	17.50	15.50
20th Aug. -	26.25	43.00	126.00	136.00	50.00	12.75	17.75	15.50
27th Aug. -	25.75	43.00	125.50	135.50	50.00	12.75	17.50	15.50
3rd Sept. -	25.25	42.50	126.00	136.00	50.00	12.625	17.50	15.00
10th Sept. -	25.75	43.00	121.00	131.00	50.00	12.625	17.50	15.00
17th Sept. -	26.25	43.75	123.50	133.50	56.00	12.75	17.50	13.50
24th Sept. -	26.00	43.75	119.00	129.00	60.00	12.50	17.50	15.50

* F.O.B. in second-hand drums.

The above prices are taken from the weekly reports of the Singapore Chamber of Commerce.

FEDERATION OF MALAYA

PRODUCTION OF PALM OIL AND KERNELS.

(In long tons as declared by Estates)

Month	Palm Oil		Palm Kernels	
	1955	1956	1955	1956
January	4,093	3,712	1,124	1,038
February	3,997	3,697	1,081	1,013
March	4,854	4,520	1,300	1,229
April	4,630	4,105	1,221	1,079
May	4,152	4,364	1,076	1,096
June	5,135	5,263	1,256	1,310
July	4,802	4,977	1,238	1,210
August	5,128	5,303	1,348	1,383
September	5,073	5,098	1,269	1,285
October	4,855		1,262	
November	4,952		1,348	
December	4,820		1,366	
Total	56,491	(41,039)	14,889	(10,643)

MALAYAN AGRICULTURAL EXPORTS,

APRIL-JUNE, 1956

Product	Net Exports in Tons			
	Year 1954	Year 1955	Apr.-June, 1955	Apr.-June, 1956
Arecanuts	5,511	13,679	4,764	4,218
Coconuts, fresh † ‡	94,433 †	72,140 †	34,720 †	12,051 †
Coconut oil ‡	78,507	91,176	18,872	25,494
Copra ‡	67,472 *	75,076 *	14,041 *	20,727 *
Copra cake	40,520 *	56,404 *	13,861 *	15,556 *
Gambier, all kinds	134 *	66	16	6
Palm Oil	48,908	52,832	12,064	13,338
Pineapples, canned	21,533	27,756	8,279	9,994
Rubber ¶	585,081 §	637,083	144,594	143,848
Sago,—flour	27,980	23,053	6,504	5,804
Sago,—pearl	5,122	5,483	1,061	1,158
Sago,—raw	27,021 *	18,709 *	3,818 *	4,444 *
Tapioca,—flake	49	475	126	69
Tapioca,—flour	4,555 *	3,979 *	859 *	947 *
Tapioca,—pearl	7,865	5,470	1,812	1,515
Derris	16	13	7	1
‡ Copra equivalent	88,943	74,528	17,320	26,113

¶ production (Federation of Malaya). † hundreds in number. * net imports.

§ This figure includes an adjustment of + 2,090 tons shown in annual returns.

FEDERATION OF MALAYA RUBBER PRODUCTION

(In long tons, dry weight)

Month	Estates		Smallholdings (Estimated)		Total	
	1955	1956	1955	1956	1955	1956
January	29,260	32,515	26,033	26,428	55,293	58,943
February	28,497	27,503	21,928	23,848	50,425	51,351
March	27,465	28,408	24,874	22,433	52,339	50,841
April	24,155	26,591	20,415	21,647	44,570	48,238
May	27,355	23,389	22,331	19,703	49,686	43,092
June	27,497	29,409	22,841	23,109	50,338	52,518
July	30,238	30,709	25,647	23,807	55,885	54,516
August	30,650	30,201	23,571	22,927	54,221	53,128
September	31,274	30,123	24,764	21,774	56,038	51,897
October	30,724		23,960		54,684	
November	30,174		21,743		51,917	
December	34,893		27,174		62,067	
Total	351,802 *	(258,848)	285,281	(205,676)	637,083 *	(464,524)
Total 1954	344,851		240,230		585,081	

This Table has been compiled from statistics published by the Chief Statistician, Federation of Malaya.

Production on smallholdings (estates of less than 100 acres) is taken as the total of purchases from smallholders reported by licensed dealers.

* These are amended figures for the year and have been taken from figures submitted by estates in their Annual Questionnaires.

FEDERATION OF MALAYA

PRODUCTION OF COPRA, COCONUT OIL AND COPRA CAKE

(in tons)

Month	Copra Production						Coconut Oil Production		Copra Cake (Poonac) Manufactured	
	Estates		Smallholdings (estimated)		Total		Oil Mills		Oil Mills	
	1955	1956	1955	1956	1955	1956	1955	1956	1955	1956
January	2,674	2,728	4,297	7,808	6,971	10,536	5,528	8,247	3,561	5,197
February	2,797	2,713	8,366	8,457	11,163	11,170	7,753	7,369	4,808	4,612
March	2,975	3,032	7,726	6,463	10,701	9,495	7,368	8,459	4,603	5,242
April	3,021	2,878	7,478	7,188	10,499	10,066	6,165	7,916	3,934	4,855
May	3,619	2,813	7,630	11,015	11,249	13,828	7,399	8,729	4,580	5,434
June	3,748	3,133	10,534	9,457	14,282	12,590	8,017	9,193	5,128	5,731
July	3,955	3,860	12,311	10,971	16,266	14,831	8,538	9,410	5,400	5,849
August	4,188	4,140	10,275	14,000	14,463	18,140	8,580	11,447	5,370	7,132
September	3,745	3,986	9,511	12,896	13,256	16,882	9,259	9,567	5,749	6,028
October	3,591		9,730		13,321		9,240		5,787	
November	2,850		8,486		11,336		9,059		5,758	
December	3,301		7,180		10,481		8,050		5,062	
Total	40,464	(29,283)	103,524	(88,255)	143,988	(117,538)	94,956	(80,337)	59,740	(50,080)

Notes:—1. The above Table has been compiled from statistics published by the Chief Statistician, Federation of Malaya.

2. Estate copra production and coconut oil production are as declared by estates and oil mills respectively.

3. Statistics of smallholding coconut oil production are not available.

4. Smallholding copra production is for commercial purposes and not production for the purpose of domestic milling in villages.

METEOROLOGICAL SUMMARY, MALAYA, AUGUST, 1956

Locality	Air Temperature Degrees Fahrenheit							Earth Temperature		Rainfall								Bright Sunshine		
	Means of			Absolute Extremes									Number of days							
	A. Max.	B. Min.	Means of A and B	Highest Max.	Lowest Min.	Lowest Max.	Highest Min.	At 1 foot °F	At 4 feet °F	Total		Most in a day Amt.	Precipitation .01 in or more	Precipitation .04 in or more	Thunderstorm	Fog morning obs.	Gale force 8 or more	Total	Daily Mean	Per cent.
										in.	mm.	in.						hr.	hr.	
Ipoh, Perak	91.0	72.7	81.9	95.0	70.6	84.0	75.8			4.60	116.8	0.97	13	11	1			173.30	5.59	
Kuala Lumpur, Selangor	89.1	72.4	80.7	93.7	70.4	84.6	74.2			6.61	167.9	2.88	14	13	8			175.00	5.65	
Sitiawan, Perak	89.1	72.8	80.9	92.2	70.1	84.4	75.2	84.4	85.4	3.97	100.8	0.89	11	9	2			194.65	6.28	
Kuantan, Pahang	88.9	71.0	79.9	92.3	67.1	81.3	74.0	82.8		5.96	151.4	1.06	20	17	9	1		185.40	5.98	
Bayan Lepas, Penang	86.3	73.2	79.7	91.5	70.2	80.0	76.0			10.51	267.0	1.92	19	15				178.75	5.77	
Malacca	86.7	72.2	79.5	89.8	69.2	83.0	74.5			8.51	216.2	1.68	20	14	4			164.35	5.30	
Mersing, Johore	87.1	71.0	79.1	89.6	69.0	77.3	73.1			8.13	206.5	2.46	15	11			2	204.20	6.59	
Alor Star, Kedah	86.1	73.4	80.1	92.0	71.8	78.9	75.7			11.77	299.0	1.70	19	17	1			175.85	5.67	
Kota Bharu, Kelantan	88.4	73.7	81.1	91.2	71.0	85.6	77.0	86.0	86.9	5.63	143.0	1.69	12	10	10		2	211.15	6.81	
K. Trengganu, Trengganu	87.2	72.8	80.0	91.2	69.5	84.4	75.9			5.47	138.9	1.60	12	9	1			198.90	6.41	
Singapore	86.8	73.5	80.1	89.4	71.0	79.0	76.4			9.36	237.7	1.66	17		6	2		168.20	5.43	
HILL STATION																				
Cameron Highlands, Tanah Rata, Pahang. (4750 ft.)	72.0	55.8	63.9	77.0	49.0	67.2	62.0			9.00	228.6	2.02	18	14				134.95	4.35	

Compiled from returns supplied by the Malayan Meteorological Service.

METEOROLOGICAL SUMMARY, MALAYA, SEPTEMBER, 1956

Locality	Air Temperature Degrees Fahrenheit							Earth Temperature		Rainfall								Bright Sunshine		
	Means of			Absolute Extremes				At 1 foot	At 4 feet	Total		Most in a day	Number of days					Total	Daily Mean	Per cent.
	A. Max.	B. Min.	Means of A and B	Highest Max.	Lowest Min.	Lowest Max.	Highest Min.	°F	°F			Amt.	Precipitation .01 in or more	Precipitation .04 in or more	Thunderstorm	Fog morning obs.	Gale force 8 or more			
										in.	mm.	in.						hr.	hr.	
Ipoh, Perak	90.5	72.3	81.4	94.0	69.2	85.6	74.5			8.27	210.1	1.98	18	16	2			159.10	5.30	
Kuala Lumpur, Selangor	88.7	71.6	81.0	91.7	69.8	85.2	73.9			9.86	250.4	2.68	20	14	6	4		150.10	5.00	
Sitiawan, Perak	88.8	72.1	80.5	92.2	70.9	85.0	74.3	84.2	85.2	5.04	128.0	0.90	15	13	1			159.45	5.31	
Kuantan, Pahang	88.7	71.6	80.1	91.7	69.8	85.2	73.9	82.9		9.86	250.4	2.68	20	14	13	7		150.10	5.00	
Bayan Lepas, Penang	85.9	73.2	79.5	90.3	70.2	79.9	75.6			14.84	376.9	2.99	17	16	3			132.30	4.41	
Malacca	87.3	72.5	79.9	91.0	70.5	80.1	74.8			2.73	69.3	0.82	14	11	1			166.60	5.55	
Mersing, Johore	87.2	70.6	78.9	92.1	68.8	81.2	73.6			8.01	203.5	2.40	19	19			4	157.65	5.25	
Alor Star, Kedah	86.0	73.6	79.8	89.6	71.6	78.4	75.0			13.00	330.2	2.13	21	20	2			129.05	4.30	
Kota Bharu, Kelantan	87.4	73.5	80.5	91.0	70.8	81.2	76.0	83.6	85.6	11.30	287.0	2.08	22	22	13			184.20	6.14	
K. Trengganu, Trengganu	86.6	72.6	79.6	89.2	71.0	79.5	75.0			10.96	278.4	2.39	16	14	1			181.85	6.06	
Singapore	86.8	74.1	80.5	90.3	70.8	81.8	79.0			4.09	103.9	1.76	14	12	2	1	1	145.80	4.86	
HILL STATION																				
Cameron Highlands, Tanah Rata, Pahang. (4750 ft.)	73.3			77.0		68.0				9.02	229.1	1.35	21	17				127.45	4.25	

Compiled from returns supplied by the Malayan Meteorological Service.